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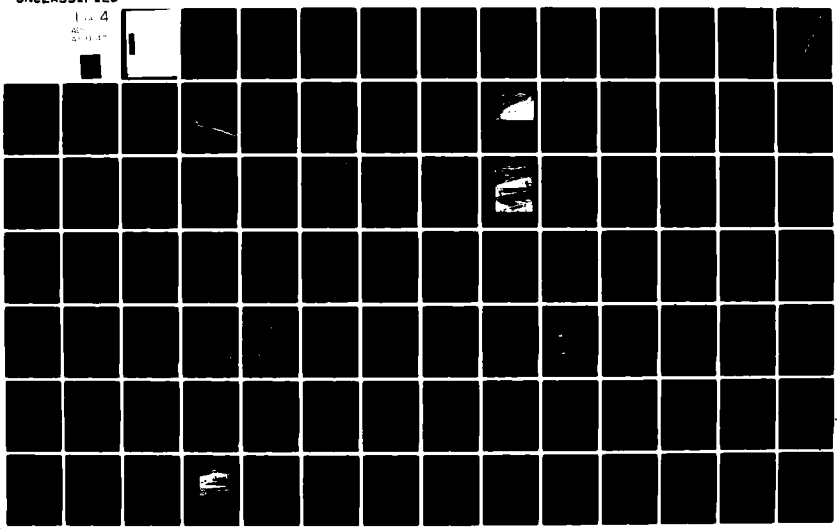

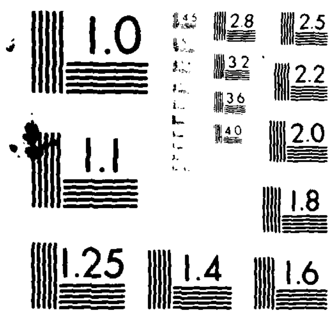

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The overall objectives of this report are to assess the impact, both positive and negative, of Corps of Engineers' activities on Pool 4 (Alma, Wisconsin) of the Upper Mississippi River. An analysis of natural and socioeconomic systems is included. The natural systems include terrestrial and aquatic plant and animal life, geology and water quality. Socioeconomic systems include industrial and recreational activities, and cultural considerations, which include archaeological and historical sites.

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FINAL REPORT

ENVIRONMENTAL IMPACT ASSESSMENT STUDY

POOL 4

of the Northern Section of the UPPER MISSISSIPPI RIVER

for the

ST. PAUL DISTRICT CORPS OF ENGINEERS
under Contract No. DACW37-73-C-0059

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FOREWORD

Purpose of the Environmental Studies

The National Environmental Policy Act of 1969 directs that all agencies of the Federal Government "include in every report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement . . . on the environmental impact of the proposed action." The Act deals only with proposed actions. However, in keeping with the spirit of the Act, the U.S. Army Corps of Engineers has developed its own policy that requires such reports on projects it has completed and for which continuing operational and maintenance support are required.

In keeping with its policy, on January 15, 1973, the St. Paul District of the U.S. Army Corps of Engineers contracted with the North Star Research and Development Institute to prepare a report assessing the environmental impact of the Corps of Engineers' operation and maintenance activities on the Mississippi River from the head of navigation in Minneapolis, Minnesota, to Guttenberg, Iowa. Included also are the Minnesota and St. Croix Rivers from their respective heads of navigation at Shakopee and Stillwater, Minnesota to the Mississippi River. This portion of the Mississippi River basin will subsequently be termed the "Northern Section" of the Upper Mississippi River, the "study area", or the St. Paul District.

The Corps of Engineers has been active in the Northern Section since the 1820's, when they first removed brush and snags from the river to permit navigation as far north as Fort Snelling. Later in the 1870's, further improvements were made, primarily through construction of wing dams, to deepen and maintain the channel. Presently, the river in the study area consists of a series of pools, which were created by the construction of navigation locks and dams in the 1930's. Several recreation areas along the river were also built by the Corps.

The purpose of the environmental impact study is to assess the impacts, both positive and negative, of the Corps' activities on the Northern Section. These activities are defined as operations and maintenance activities and mainly include operations of facilities (locks and dams) and maintenance of the navigation channel (dredging). Actually, the impacts on the environment of the earliest operations are also being sought, but most of the information will concern those of the present navigation system.

The studies are designed not only to identify the impacts, but to assess their effects on both the natural and social environment. Such impacts may include effects of river transportation on the area economy, effects of creation of the pools on recreational activities and wildlife habitat, effects of dredge spoil disposal on the natural ecosystem and on recreation, and many others. As a result of identification and assessment of the impacts, it may be possible to suggest ways of operating the

facilities and maintaining the navigation and recreation system to amplify the positive and minimize the negative results of the Corps' activities. The study will provide a comprehensive basis for the St. Paul District to prepare an environmental impact statement consistent with the National Environmental Policy Act of 1969 and the policy of the U.S. Army Corps of Engineers.

Scope of Current Report

The present report covers the entire study program from January, 1973 through November, 1973. The report contains both historical information and data collected in the field from activites such as water sampling and wildlife observation.

Research Approach

Three aspects of the research approach used in the study are: (1) the benchmark point in time, (2) data collection and anlysis on the natural systems, and (3) data collection and anlysis on the socioeconomic activities.

Benchmark Time Period

In order to analyze the impact of the activities of the Corps of Engineers on the Northern Section of the Upper Mississippi River, it is necessary to select a time period that can serve as a benchmark. This benchmark represents the state of the Mississippi River prior to the time activities related to the nine-foot channel were initiated. Because the

nine-foot channel project was constructed in the 1930's, the preconstruction benchmark was taken as 1930. Wing-dams were built and other Corps' activities took place prior to 1930, however, and earlier data were also used where they were readily available. The preconstruction benchmark data were obtained from available reports and from a variety of other sources cited at the end of each section.

Analysis of the Natural Systems

The impacts of Corps' activity on the natural environment for a given pool were determined by the individual investigator responsible for that particular pool. The Northern Section of the Upper Mississippi River was subdivided into fourteen distinct segments for purposes of study of the natural environment: Pools 1 through 10, Pool 5A (lying between Pools 5 and 6), the Upper and Lower Saint Anthony Falls (SAF) Pools (a single report covers both pools), the Minnesota River, and the St. Croix River. A segment was assigned to an investigator on the natural sciences team as listed below:

Number of River Segments Involved	Total Length in River Miles	River Segment	Responsibility	Organization
5	92.4	Upper and Lower Pools, Pool 1, Pool 2, Minnesota River and St. Croix River	Roscoe Colingsworth	North Star Research and Development Institute, Minneapolis, Minnesota
1	18.3	Pool 3	Edward Miller	St. Mary's College Winona, Minnesota

4	82.6	Pools 4, 5, 5A & 6	Calvin Fremling	Winona State College Winona, Minnesota
2	35.1	Pools 7 & 8	Thomas Claflin	University of Wisconsin at LaCrosse, LaCrosse, Wisconsin
1	31.3	Pool 9	James Eckblad	Luther College, Decorah, Iowa
1	32.8	Pool 10	Edward Cawley	Loras College, Dubuque, Iowa

Because different problems arise in different segments of the river, each investigating team used its own judgment in conducting its studies. However, North Star—in conjunction with the investigators cited above—developed general guidelines for conducting the field studies, acquiring data, and presenting the data in a final report. This required that North Star develop a reporting format that could be used for all pool reports so that the series of reports would have maximum utility and comparability.

Analysis of Socioeconomic Activities

The socioeconomic analysis for all pools in the study area was conducted by a team including Dr. C. W. Rudelius of the University of Minnesota and William L. K. Schwarz of North Star. The socioeconomic impacts were analyzed by the same team for all fourteen segments of the Northern Section because substantial economies in data collection were possible with this approach. The initial data for each pool were collected and then were submitted for review and updating to the investigator analyzing the natural systems for that pool. The suggestions of these

investigators were incorporated in the socioeconomic portions of each pool report.

Report Objectives

Because the Corps is required to submit an environmental impact statement for each pool and tributary in the Northern Section on which they carry out operation and maintenance activities, this study is being carried out and reported on by pool (and tributary).

The present report deals only with Pool 4 on the Upper Mississippi River, described in detail in subsequent pages. Background information that applies to two or more pools in the study area appears as a portion of each appropriate report. This is necessary since the report on each pool must be capable of being read and understood by readers who are interested only in a single pool.

The overall objectives of this report are to identify and provide an assessment of the impacts of the Corps of Engineers activities related to Pool 4. Specifically, following this section, the report is in the format required for the Environmental Impact Statement, and seeks:

1. To identify the environmental, social, and economic impacts of the Corps activities related to Pool 4.
2. To identify and, where possible, measure the beneficial contributions and detrimental aspects of these impacts and draw overall conclusions about the net effects of Corps' activities.

3. To recommend actions and possible alternative methods of operations that should be taken by the Corps of Engineers and other public agencies and private groups to reduce detrimental aspects of the project.

4. To identify additional specific research needs to assess the impacts and increase the net benefits of Corps operations.

The report includes an analysis of natural and socioeconomic systems. The natural systems include terrestrial and aquatic plant and animal life as well as the nature of the land and quality of the water. Socioeconomic systems include industrial activities, such as income and employment generated by barge traffic or activities in operating the locks and dams and commercial fishing; recreational activities, such as fishing, boating, or hunting that are affected by Corps operations; and cultural considerations, which include archaeological and historical sites.

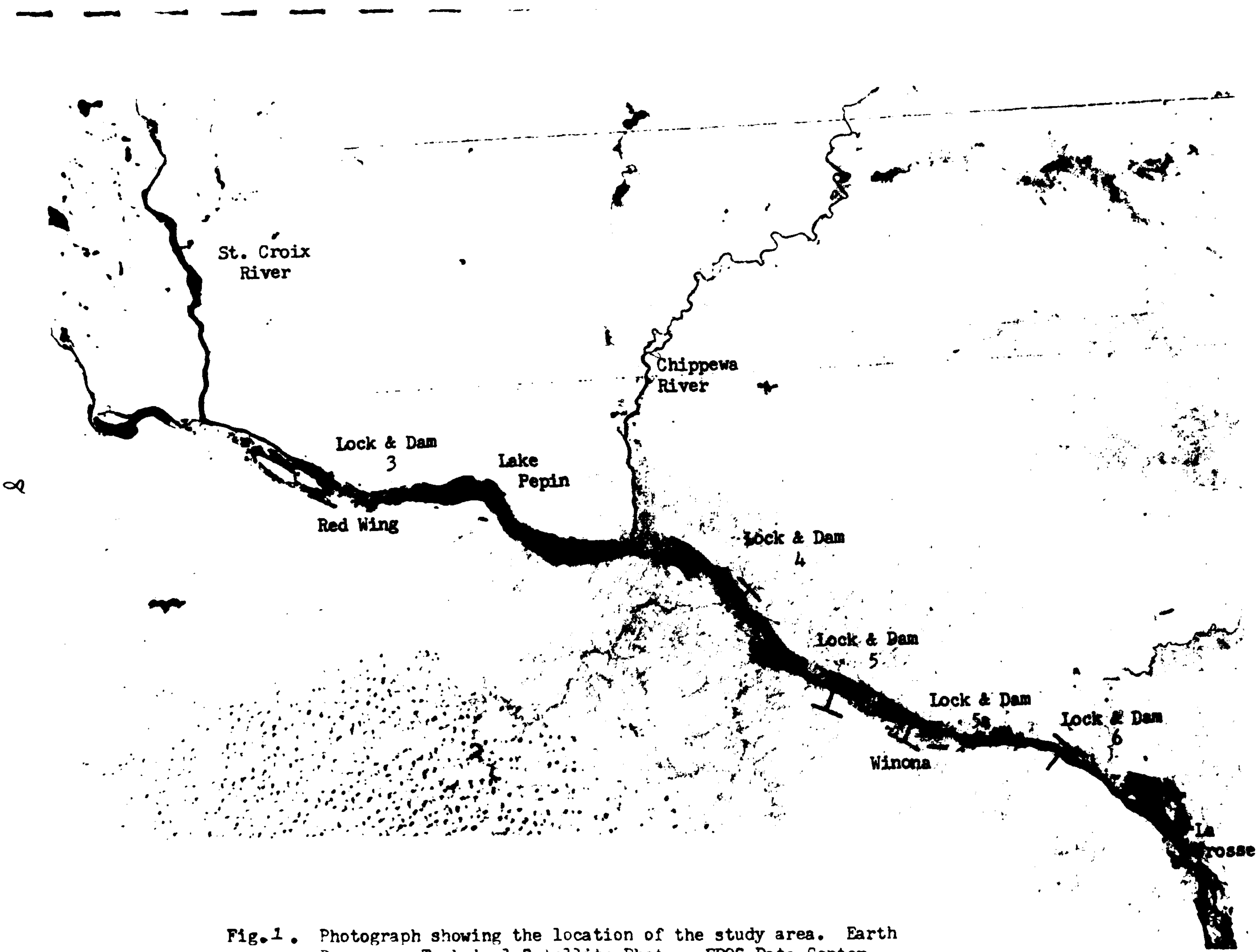


Fig. 1. Photograph showing the location of the study area. Earth Resources Technical Satellite Photo. EROS Data Center, Sioux Falls, S. D.

1. PROJECT DESCRIPTION

The Upper Mississippi River 9-foot channel was designed to provide a minimum depth of 9 feet for navigation from the mouth of the Missouri River to Minneapolis. To accomplish this objective a series of 29 locks and 28 dams have been constructed by the U. S. Army Corps of Engineers. Figure shows a profile view of the series of "steps" which towboats and pleasure boats "ascend" or "descend" as they travel upstream or downstream. In the St. Paul District, the movable section of the dams consists of tainter gates, roller gates or a combination of both (Figures ?,?). Earth dikes and overflow spillways, where required, complete the dams. The dams are designed for navigation purposes only (except for some power generation at upper St. Anthony Falls and Dam No. 1) and they serve no flood control functions. Recreational activities such as boating, fishing and hunting have been aided incidently by construction of the dams. The location of the project is shown in Figure

Prior to the 1930's the river bottoms were primarily wooded islands separated by deep sloughs. Hundreds of lakes and ponds were scattered through the wooded bottoms. Bay meadows and small farming areas occupied some areas on larger islands. Marshes were limited to the shores of lakes and guts leading off the sloughs. Marsh flora was also limited, with river bulrush making up the dominant habitat. Most marshes, lakes and ponda generally dried up completely by the end of the summer. Thus, the uncontrolled river was subject to wide fluctuations of water levels, ranging from flooding in the spring to drying out of the river bottom land in the summer.

Each lock and dam has created an extensive pool of water. In each of the pools, three distinct zones occur. The upper end of each pool remains essentially like the original river where the water levels are not raised to any extent and the old condition of deep sloughs and wooded islands is found. In the middle of each pool, water backs up over the islands and old hay meadows, spreading out and forming large areas of comparatively shallow water. In the lower end of the pool and immediately above each dam, an open lake-like aspect is found. Prior to inundation, the forests at the foot of each pool were clear cut. As a result, the pool areas contain expansive fields of submerged or partially submerged stumps.

Dredging, required in approximately 20% of the channel, entails the disposal of several million cubic yards of sand and silt each year. This generates a problem that intrudes on the natural aspect of the pool areas. Sandbars or spoil areas, varying in extent from less than one acre to more than 100 acres have been formed throughout the project. These deposits are ranged on either side of the navigable channel in staggered spots as occasioned by the need for dredging in any particular section.

The U. S. Coast Guard has placed navigation aids such as buoys, day markers, and lights to guide pilots of towboats and small boat operators along safewater ways throughout the entire length of the project.

In addition to the above, the project includes the necessity for manipulation of facilities to raise, steady or lower water levels. This

manipulation is commonly referred to as operation and maintenance.

Operations include lock operations and dam operations (reservior regulations). During high water periods, emergency operations are also included.

Maintenance includes dredging the navigation channel and harbors to a minimum 9-foot depth, disposing of the dredge spoil, clearing debris from the channel and maintaining the locks and dams in good operating condition.

AUTHORIZATION

The earliest recognition of navigational problems on the Mississippi River by the Federal Government was in 1824 when it ordered a project to remove snags downstream from the Missouri River. Subsequently, spot work such as removal of sand bars and rock from rapids was undertaken until 1878 when a 4½-foot channel was ordered from St. Paul to St. Louis. This was to be accomplished by construction of wing dams and closing dams, bank rip-rap and revetments to increase the scouring action of a confined flow, and by dredging trouble spots. Although it was funded yearly by Congress, the 4½-foot channel project was not substantially finished until 30 years later, in 1907.

In that same year, the Inland Waterways Commission urged a general plan for the river that would include not only navigation, but flood control, water supply and power development. Nothing was done on the

larger proposal, but work began on deepening the upper river channel from $4\frac{1}{2}$ to 6 feet using the same methods as before. The project was only half completed in 1925 when the Army Engineers decided that the 6-foot depth would not be possible the entire length of the river using present methods. In any case, the River and Harbors Act of 1927 abondoned the 6-foot proposal and authorized an eventual 9-foot channel which was needed for the big barges that made river commerce economically feasible. President Hoover signed the bill authorizing the 9-foot channel in 1930. The 9-foot project was by far the most ambitious yet attempted. It called for a series of 27 locks and dams above St. Louis and it was finally completed in 1939 (Dosch, 1970). Table I lists acts pertinent to the portion of the 9-foot channel encompassed by Pools 4, 5, 5A and 6.

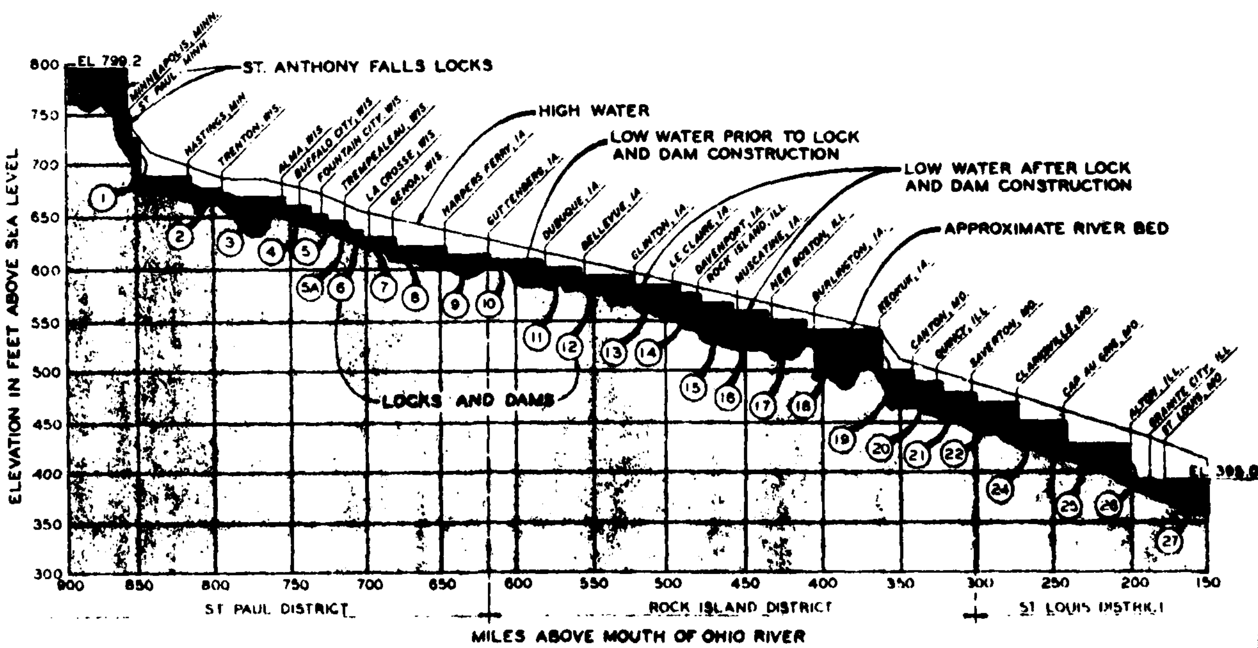


Fig. 2. The 9-foot channel project has changed the Upper Mississippi River into a series of "steps" which river tows "climb" or "descend" as they travel upstream or downstream.

TABLE I

Congressional Authorization of Navigation

Project in Pools 4, 5, 5A and 6, Upper Mississippi River

EXISTING PROJECT WAS AUTHORIZED BY THE FOLLOWING

Project	Acts	Work authorized	Documents
Mississippi River between Missouri River and Minneapolis, Minn.	Sept. 22, 1922 July 3, 1930 as amended by P.R. No. 10, Feb. 24, 1932.	Dredging channels to landing places. Project adopted from Illinois River to Minneapolis: Chief of Engineers granted discretionary authority to make such modification in plan as may be deemed advisable	None H. Doc. 290 71st Cong., 2nd sess.
	Mar. 2, 1945	Red Wing, Minn. harbor	H. Doc. 103 76th Cong., 1st sess.
	Mar. 2, 1945	Remedial works to correct damages caused by seepage and backwater at Cochrane, Wis.	H. Doc. 137 76th Cong., 1st sess.
	Mar. 2, 1945	Winona, Minn. basin.	H. Doc 263 77th Cong., 1st sess.
	July 24, 1946	Lake City, Minn. harbor	H. Doc. 511 2d sess. 79th Cong.,
	July 24, 1946	Wabasha, Minn., harbor	H. Doc 514 79th Cong., 2d sess.
	July 24, 1946	Payment of damages caused by backwater and seepage, pools 3 to 11.	H. Doc. 515 79th Cong., 2d sess.
	May 17, 1950	Alma, Wis., harbor	H. Doc 66 81st Cong., 1st sess.

TABLE I (cont)

Project	Acts	Work authorized	Documents
	May 17, 1950	Permits such change in location of Winona, Minn., small boat basin authorized by River and Harbor Act of Mar. 2, 1945 (H. Doc. 263 77th Cong., 1st sess.) as Chief of Engineers deems advisable.	None
	Sept. 3, 1954	Construction of Crooked Slough Harbor at Winona, Minn., in lieu of previously authorized	H. Doc. 347, 83rd Cong., 2d sess.
	July 14, 1960	Construction of Industrial Harbor at Red Wing, Minn.	H. Doc. 32 86th Cong., 1st sess.
	Oct. 23, 1962	Construction of small-boat harbors at Savanna, Moline, Andalusia, New Boston, Warsaw, Quincy, and Grafton, Ill: Bellevue, Clinton, Davenport, and Keokuk, Iowa; St. Paul (Harriet Island), Minn.; and Bay City, Pepin, and Cassville, Wis.	H. Doc. 513 87th Cong., 2d sess.

HISTORY

The Mississippi is the largest river in the United States. From its source at Lake Itasca, in Northern Minnesota, it winds 2,319 miles to its mouth in the Gulf of Mexico, 95 miles downstream from New Orleans. The Mississippi and its tributaries drain about 41% (about 1,233,000 square miles) of the total area of the United States. By definition, the segment upstream from the mouth of the Ohio River, at Cairo, Illinois, is called the Upper Mississippi River (U. S. Army Corps of Engineers, 1958). The segment from the Gulf of Mexico to Cairo is termed the Lower Mississippi River (U. S. Army Corps of Engineers, 1965). The river is presently navigated by 9-foot draft vessels as far upstream as Minneapolis.

One hundred and forty-seven years ago, in 1823, the first steamboat probed its way up the Mississippi River as far as the present site of St. Paul. The next year, government-owned and operated boats began to improve the river for navigation by removing snags, boulders and other obstructions. In 1829, Captain Henry Shreve was commissioned to construct and operate a special twin-hulled snag boat on the upper river. It was imperative to the growth of the U. S. that the river be improved to provide a water highway to the sea because the interior of the continent was relatively inaccessible to overland freight haulers. Early channel improvements, however modest, enabled the United States to quickly exploit the interior of the entire North American continent. By the 1870's hundreds of shallow-draft steamboats routinely navigated the Upper Mississippi River.

Loggers used the river, too (Russel, 1928). By means of the Chippewa,

the Black, the Wisconsin and smaller Wisconsin rivers, they quickly exploited the pineries of northwest Wisconsin, floating hugh rafts of saw logs down to the Mississippi and then down to the sawmills of Winona, LaCrosse, Clinton and Rock Island. At one time there were over 80 sawmills on the upper river and at least 120 more on tributary streams.

In 1878, the U. S. Army corps of Engineers was authorized by a Congressional Appropriation Act to deepen the navigable channel of the Mississippi River to four and one-half feet so that larger boats with deeper draft could operate on the river.

The project was accomplished by building wing dams and closing dams and by narrowing the river to 800 feet (Fugina, 1945; Turner, 1969; U. S. Army Corps of Engineers, 1962). Wing dams were built at right angles to the shore to deepen the channel by scouring. Closing dams were constructed across side channels with the function of diverting all river flow into the main channel. Wing dams were usually built in a series with the shorter ones on the up-river end. The action of the current around the ends of the wing dams scoured a channel and deposited the sand in eddies behind the dams. Fugina, a life-long river pilot, observed that the spaces between the wing dams rapidly filled with sand as high as the dams. Willows soon sprouted on these sandbars, and new islands were created in a few years.

Wing dams were constructed of willows cut in the river bottoms and dolomite quarried from nearby bluffs. The rock and willows, which were

Figure 5. View from Buena Vista Bluff at Alma, Wisconsin. The photograph was taken in about 1900 and it shows steamboats pushing log rafts downstream toward saw mills in Winona or some other lumber center. The logs were rafted from Wisconsin pineries via the Chippewa River to the Mississippi. Photo courtesy of Winona County Historical Society.

tied in bundles 20 feet long and 12 inches in diameter, were barged to the site of the dam. At the dam site the bundles of willows were carried aboard a building barge and woven into mattresses. The mattresse were skidded into the river and held in place by ropes until sufficient rock could be loaded on the mattresses to sink them, layer after layer, into the river. The dams were built in from 5 to 40 feet of water and were constructed so that they projected as much as 6 feet above the water.

Shore protection was a vital part of the channelization project. Timber, leaning tree and stumps were removed from the shoreline which was then graded to a three to one slope and faced with layers of brush covered with stone. Troublesome sanbars were removed by a dipper-type dredge. By 1905, the four and one-half foot channel was a reality between St. Louis and the Washington Avenue Bridge at Minneapolis.

Meanwhile, larger, more powerful riverboats had evolved and they needed a deep channel to carry greater pay loads. Additional funds were appropriated by Congress in 1907 to deepen the navigable channel to 6 feet. This was accomplished by building additional wing dams, closing dams,and by dredging. Usually, on the opposite side of the river from the wing dams, the shore was fortified with rock so that water which rushed around the ends of the wing dams did not erode away the opposite shore. Thus, the extreme channelization begun in 1878 was finally completed in 1912.

The short-lived logging boom which began in 1875 hit its peak in 1892; and in 1915 the Ottumwa Belle snaked the last remnants of Wisconsin

lumber down the Mississippi River. Six foot draft steamers also began to disappear from the upper river because they could not compete with the railroads.

Owers of flood plain land between LaCrosse and Prairie du Chien proposed, during the early 1920's, that their land be drained so that it would be suitable for agriculture. The proposed reclamation project was to include timber clearing, construction of dikes to protect the land from high water and the digging of internal ditches to drain the land toward pumping stations where the drainage water would be pumped over the dike. The land owners proposed that drainage districts be created under state law and that drainage costs be charged against the land to be benefited. Opponents of such reclamation insisted that the flood plain areas should be preserved for recreation and for the conservation of plant and animal life. The Isaak Walton League of America which strongly supported the parties opposing drainage, requested the Department of Agriculture to investigate the practicability of reclaiming flood plain land between St. Paul, Minnesota, and Rock Island, Illinois. As a result, a reconnaissance survey was made to determine the use and potential value of the flood plain land (Marsden and Shafer, 1924).

The survey revealed that there were about 343,000 acres of flood plain land between St. Paul and Rock Island and that the principal agricultural use of the land was for pasturage for cattle in dry seasons. Less than a fourth of the land was mowed for hay and only a very small part was cultivated. Reclamation of about 10,000 acres of the land had

already been accomplished by 1924. Most of this early land reclamation was done in Wisconsin where 6,600 acres of bottom land in Buffalo and Trempealeau counties had been drained by 1912. Because of a break in a dike in 1913, most of the area was flooded and no pumping was done between 1913 and 1924. The land reclamation program was abandoned and most of this land ultimately became the Delta Fish and Fur Fram. A second drainage district of 3,600 acres was completed just below Savanna, Illinois in 1925. The survey reported that another 86,000 acres could be reclaimed at an average ditching and diking cost of $45 to $75 per acre. Operation and maintenance of the drainage pumping plants were to be provided by an additional annual assessment. Farm land thus created was to be utilized for growing corn, the report continued, because the dairy farmers on the hills bordering the Mississippi were reported to have insufficient land suited to the growing of corn and were forced therefore, to import cattle feed from other states.

During the time that the reclamation feasibility study was being done, the Isaac Walton League of America intensified its efforts to reserve vast areas of Mississippi River flood plain for a wildlife and fish refuge.

Primarily because of the enthusiastic sponshorship of the Isaac Walton League, the United States Congress on June 7, 1924 authorized appropriations aggregating $1,500,000 for purchase of Mississippi bottom lands on a willing seller basis to be administered as the Upper Mississippi River Wildlife and Fish Refuge (Steele, 1933.) The refuge extended from the foot of Lake Pepin to Rock Island, Illinois.

The River and Harbors Act of 1930 authorized the Corps of Engineers to modify the obsolete 6-foot channel to provide a minimum depth of 9 feet and a minimum width of 400 feet (U.S. Army Corps of Engineers, 1962). This was achieved by the construction of a system of locks and dams, supplemented by dredging. The proposed nine-foot channel project created considerable controversy along the river. In numerous pronouncements, the Isaac Walton League of America condemned the 9-foot channel plan as detrimental to the environment. The League was especially concerned that erosion and pollution be controlled before the project was begun.

Winters of outdoor columns in newspapers were vocal in condemning the 9-foot channel project. For example, the Voice of the Outdoors (Winona Republican Herald, July 26, 1930) stated,

> ....we are still against the alleged nine-foot channel under the dam form of construction. We are now more firmly convinced than ever that it will be a gigantic commercial failure and will be impossible to maintain without spending millions of dollars each year in dredging operations. It will completely destroy bass fishing on the river and will form a series of badly polluted pools that will look like a lot of link sausages on a map and smell worse than said sausage if they were left exposed to the present heat for a week. The scenic attraction of the river will be completely wiped out.

Many observers expressed concern that soil erosion would constitute a severe problem in the proposed navigation pools. C. G. Bates, a forestry engineer, was quoted by the Voice of the Outdoors (Winona Republican Herald, July 23, 1930) as predicting that the proposed pools would be completely filled with sand in a period of 20 years.

The U. S. Bureau of Fisheries viewed the 9-foot channel project with

serious misgivings. The following are direct quotes from the Bureau's written testimony presented at a hearing in Wabasha (Culler, 1931).

> The Bureau of Fisheries views with much concern the establishment of a series of slack water pools along the Upper Mississippi River until the problem of pollution and erosion as they affect this upper section of the Mississippi River are solved. If the lake formed by the Keokuk Dam may be taken as a criterion, the creation of similar pools may mean the eventual elimination of all fish life inasmuch as the production of fish in Lake Cooper, which is formed by the Koekuk Dam, has declined according to the official statistics of the Bureau of Fisheries from 701,181 pounds in 1922 to 350,750 pounds in 1929.
>
> The construction of slack water pools such as the one that is contemplated at this time and in this particular section north of Winona, will mean the eventual elimination of the smallmouth black bass for which this section is so widely known.

The U.S. Bureau of Biological Survey (Henderson, 1931) reported on the other hand, that the 9-foot channel project could be beneficial to waterfowl and muskrats if water levels were stabilized. The Bureau's conclusions were based on a comprehensive study of the biological effects of Lock and Dam 19 on the Mississippi River. The following is a direct quote from Henderson's report:

> It is very probably that considerable portions of the Upper Mississippi River Wildlife and Fish Refuge would be benefited by the construction level above a maximum of five feet in depth over the newly flooded bottomlands, provided that stable water levels are maintained throughout the year. The construction of these dams will undoubtedly make an entirely different type of Refuge, for most of the bottomland timber will be destroyed and the percentage of land unaffected by the flooding will be relatively small. Immediately following the construction of any system of dams flooding the lowlands, an adverse period must be anticipated, but following the re-adjustment and re-establishment of the aquatic and marsh vegetation, the Refuge should be an improved place for waterfowl and probably also for muskrats.

Prior to the formation of the 9-foot channel impoundments, water levels fluctuated greatly throughout the year. Spring floods submerged lowland areas and as the flood waters receded, pools and lakes cut off from the main channel of the river were formed. Conditions were favorable for the growth of newly-hatched fish in such flood plain lakes, but the stranded fish usually died as water levels receded and the lakes dried up. Those land locked fish which survived the summer were usually killed by freeze outs during the winter.

During the late 1870's programs were begun to rescue land locked fish and to return them to the river or to use them to stock inland waters (Carlander, 1954). The projects proved to be a much more economical way to obtain young fish for stocking than to rear them in hatcheries. Both state and federal fish rescue programs were in operation along the Upper River until the 9-foot channel project was begun. The U.S. Bureau of Fisheries employed about 50 men each year to rescue stranded fish. In 1929 the Bureau rescued 155,477,000 fish and in 1928 the number rescued was 147,000,000 (Voice of the Outdoors, Winona Republican Herald, July 22, 1930).

Fluctuating water levels allowed marshes to dry prior to stabilization of water levels by the 9-foot channel project. During dry years the entire refuge throughout its 284 mile length became almost at once a virtual tinder box. Wild fire was a constant threat (Steele, 1933).

By 1930, the Upper Mississippi River Wildlife and Fish Refuge encompassed about 87,000 acres of flood plain land. The 9-foot channel project enabled the U. S. Army Corps of Engineers to condemn land to

obtain flowage rights and it became obvious that it was needless for federal wildlife interests and federal navigation interests to compete for land. Consequently, the Bureau of Sport Fisheries and Wildlife gave the U. S. Army Corps of Engineers flowage rights on refuge land in return for wildlife management rights on land owned by the Corps. By this means, the Upper Mississippi River Wildlife and Fish Refuge was increased to about 195,093 acres. Of this total, 23,261 acres lie in Illinois, 50,639 in Iowa, 33,004 in Minnesota and 88,189 in Wisconsin (data summarized from Official Acreage Book, U. S. Bureau of Sport Fisheries and Wildlife Office, Winona, Mn.).

Most of the 29 locks and dams necessary for the 9-foot channel project were constructed during the 1930's. A notable exception is Loak and Dam 19 at Keokuk, Iowa, which was constructed as part of a hydroelectric facility in 1914. The navigation locks are operated and maintained by the Corps of Engineers, but the U.S. Coast Guard is responsible for the maintenance of the elaborate system of navigation aids which guide modern towboats as they navigate the river around the clock from early spring until early winter.

The huge navigation dams of the Upper Mississippi have transformed the river into a series of impoundments which occupy most of the flood plain of the river. Consequently, the river is much wider at LaCrosse, Wisconsin, than it is at New Orleans. Each impoundment consists of three distinct ecological areas. The tailwater areas just downstream from the dams show the river in relatively unmodified form. The areas are typified by deep sloughs and wooded islands. The middle portions of

the pools are principally flooded hay meadows. They now provide the best marsh habitat. The downstream ends of the pools are deeper, however. They consist mainly of open water and their bottoms are heavily silted. Marsh vegetation is presently creeping downstream as the pools silt in. Marsh vegetation in the middle pool areas is being replaced, in turn, by trees and other terrestrial vegetation.

The old wing dams and closing dams, still partially functional, now lie beneath the water. The wing dams provide rocky corrugations on the river floor, so that they, in effect, have increased the total surface area of the river bottom - thus increasing its carrying capacity for invertebrates such as hydropsychid caddisflies and periphyton. Impoundment has also increased the surface area of the river, thereby increasing the area of the trophogenic zone.

The seven-county area which contains metropolitan Minneapolis and St. Paul contains about 1/3 of Minnesota's population and the population in the seven-county area is expected to double in the next 30 years. The people of the seven-county area exert a profound influence on the Mississippi River.

The river has been severely polluted for many years for about 60 miles through the downstream from metropolitan Minneapolis and St. Paul (Metropolitan Drainage Commission of Minneapolis and St. Paul, 1928). In the metropolitan area about 1,768,000,000 gallons of industrial and municipal waste water enter the river each day. About 85% of this amount is cooling water from steam-electric generating plants (Federal Water

Pollution Control Administration, 1966). Although they were not constructed for that purpose, the navigation pools serve as sewage lagoons so that with each subsequent impoundment and aeration in the tailwaters, the putrescible portion of the metropolitan pollutant load is decreased. Downstream cities add more pollutants but their additions are very small compared to those of Minneapolis and St. Paul. Also, large tributary rivers such as the St. Croix, Chippewa and Wisconsin add relatively clean water to the Mississippi thus increasing its ability to assimilate its pollutant load. Biologically, the Upper Mississippi River is comparatively clean from Wabasha, Minnesota (mile 760 Upper Mississippi River), to the mouth of the Illinois River just above St. Louis.

CORPS FACILITIES

Lock and Dam No. 4, River Mile 752.8, Alma, Wisconsin was placed in operation on May 25, 1935. The Pool formed extends 44.1 river miles upstream from this point to mile 796.9. A total of 10,412.24 acres of Pool 4 are owned or controlled by the U.S. Government. Of this total, 2,899.68 acres are fee title lands, 977.69 acres are flowage easement lands and 6,534.87 acres are special rights lands of the Department of the Interior.

Fee title lands include acreages which were approved and granted by General Plans and Coopreative Agreements to the Department of the Interior, Bureau of Sport Fisheries and Wildlife for the conservation, maintenance and management of wildlife, and wildlife habitat in connection with the National Migratory Bird Management Program. Special rights lands

TABLE II
LOCK AND DAM NO. 4

Condition of Improvement, 30 June 1970

Progress:

Lock completed 5 January 1934.
Dam completed 26 June 1935; placed in operation 25, May 1935.
Construction remaining: Extension of upper guide wall;

Lands:

Land in Pool 4 owned or controlled by United States:

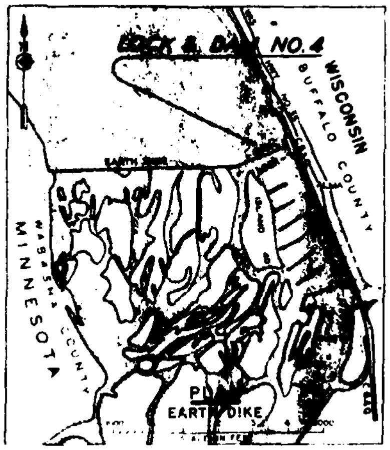
Fee title	2,899.68 acres (1)
Flowage easement	977.69 acres
Special rights, Department of Interior	6,534.87 acres
Total	10,412.24 acres

(1) Includes 2,898 acres, use of which was approved and granted by General Plans and Cooperative Agreement to the Department of the Interior, Fish and Wildlife Service, for the conservation, maintenance and management of wildlife, resources thereof and its habitat thereon, in connection with the National Migratory Bird Management Program.

Cost of Construction:

Designs	$ 142,776
Lands	1,064,280
Lock	951,463
Dam dikes	2,465,216
Electrical	88,875
Other	152,124
Recreational facilities (design)	6,593
Total cost to date	$4,871,327

22



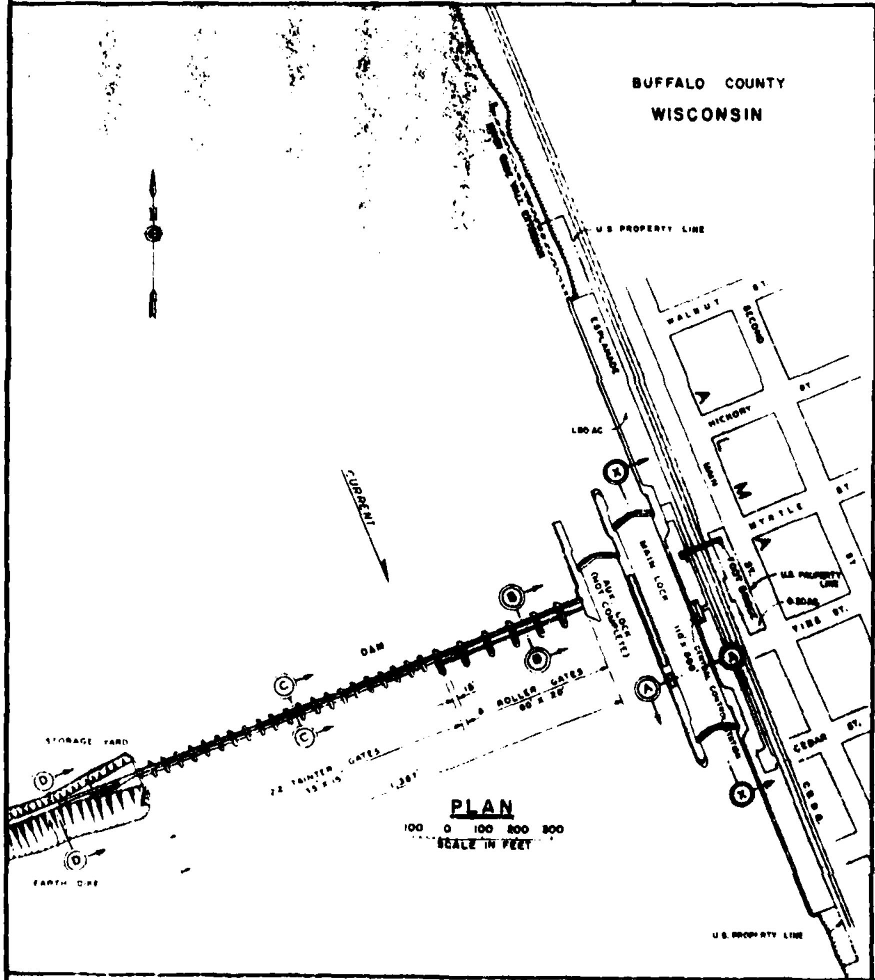


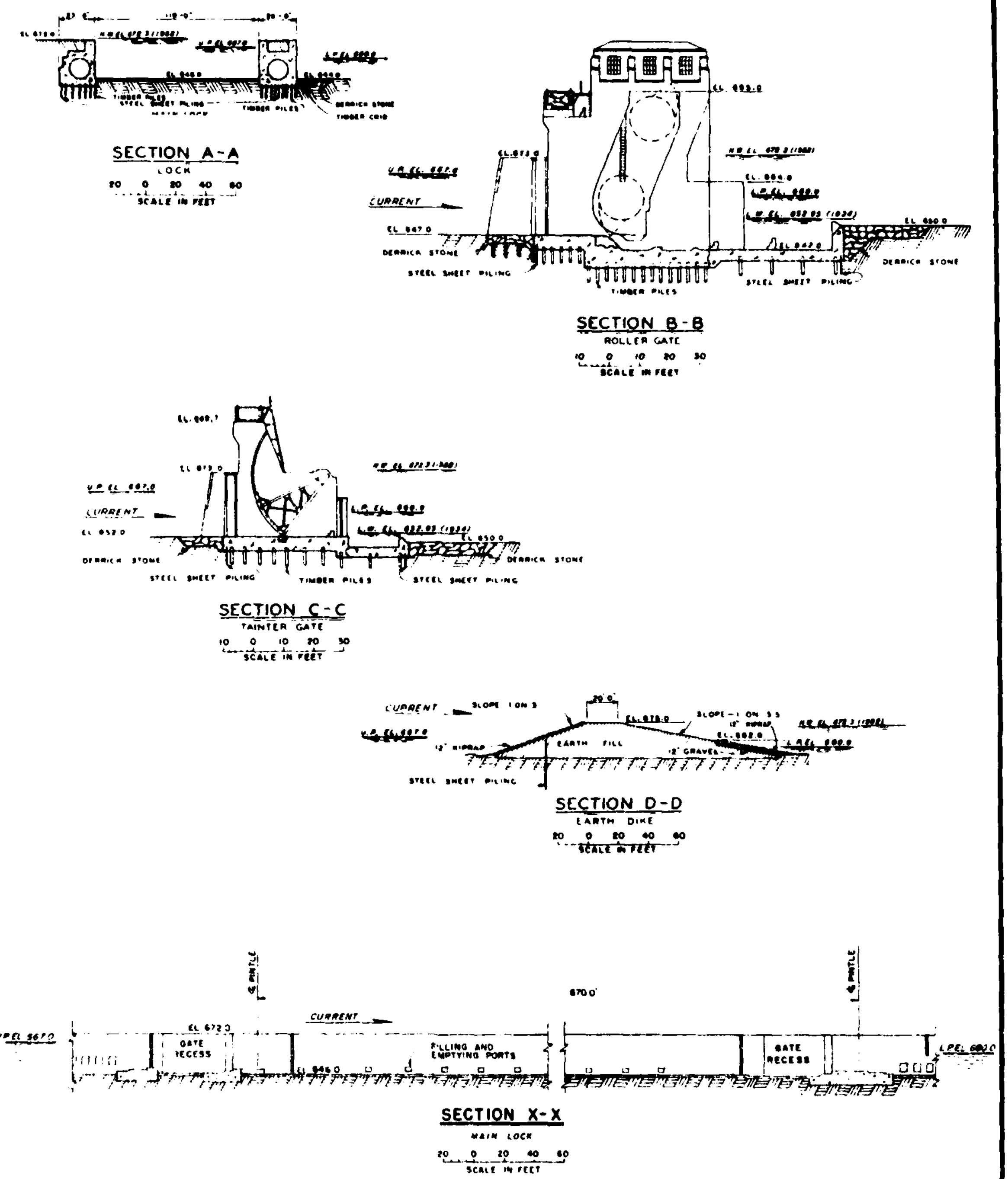
Fig. 3

RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
MISSOURI RIVER TO MINNEAPOLIS, MINN.

LOCK & DAM NO. 4

SCALE AS SHOWN

CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINN.
30 JUNE 1966



ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

Fig. 4

RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
MISSOURI RIVER TO MINNEAPOLIS, MINN.

LOCK & DAM NO. 4

IN 2 SHEETS SHEET NO 2
SCALE AS SHOWN

CORPS OF ENGINEERS U S ARMY
OFFICE OF THE DISTRICT ENGINEER
ST PAUL DISTRICT ST PAUL, MINN
JUNE 1961

are those purchased by the Department of the Interior for inclusion in the Upper Mississippi River Wildlife and Fish Refuge.

The lock and dam unit controlling water level in Pool 4 consists of a 1,367-foot movable crest dam containing a battery of 22 tainter gates and a series of 6 roller gates, one navigation lock, 600 feet long and 110 feet wide, an uncompleted auxiliary lock, and an earth dike 5,496 feet long.

In Pool 4 there are 89 rock and willow wing dams placed to constrict channel flow and increase scouring action. Almost all were built prior to the 9-foot channel project. In addition there are 30.9 miles of rock rip-rap placed along the river banks in the Pool.

The lock is closed by a pair of miter gates and the level is changed 7 feet by gravity flow through filling and emptying ports by a system of valves and pipes. Pool elevation is maintained at 667 feet above mean sea level (1912 Adjustment) by the 28 gates mentioned above. The site also includes equipment buildings, an access road, an elevated walkway and observation deck for visitors to view locking operations.

Lock and Dam 5, River Mile 738.1, Minnesota City, Minnesota was placed in operation on May 29, 1935. The pool formed extends 14.7 river miles upstream from this point to mile 752.8.

A total of 11,296.74 acres are either owned or controlled by the U. S. Government in Pool 5. Of this total, 7,565.04 acres are fee title lands, 2,368.89 acres are flowage easement lands and 1,362.81 acres are

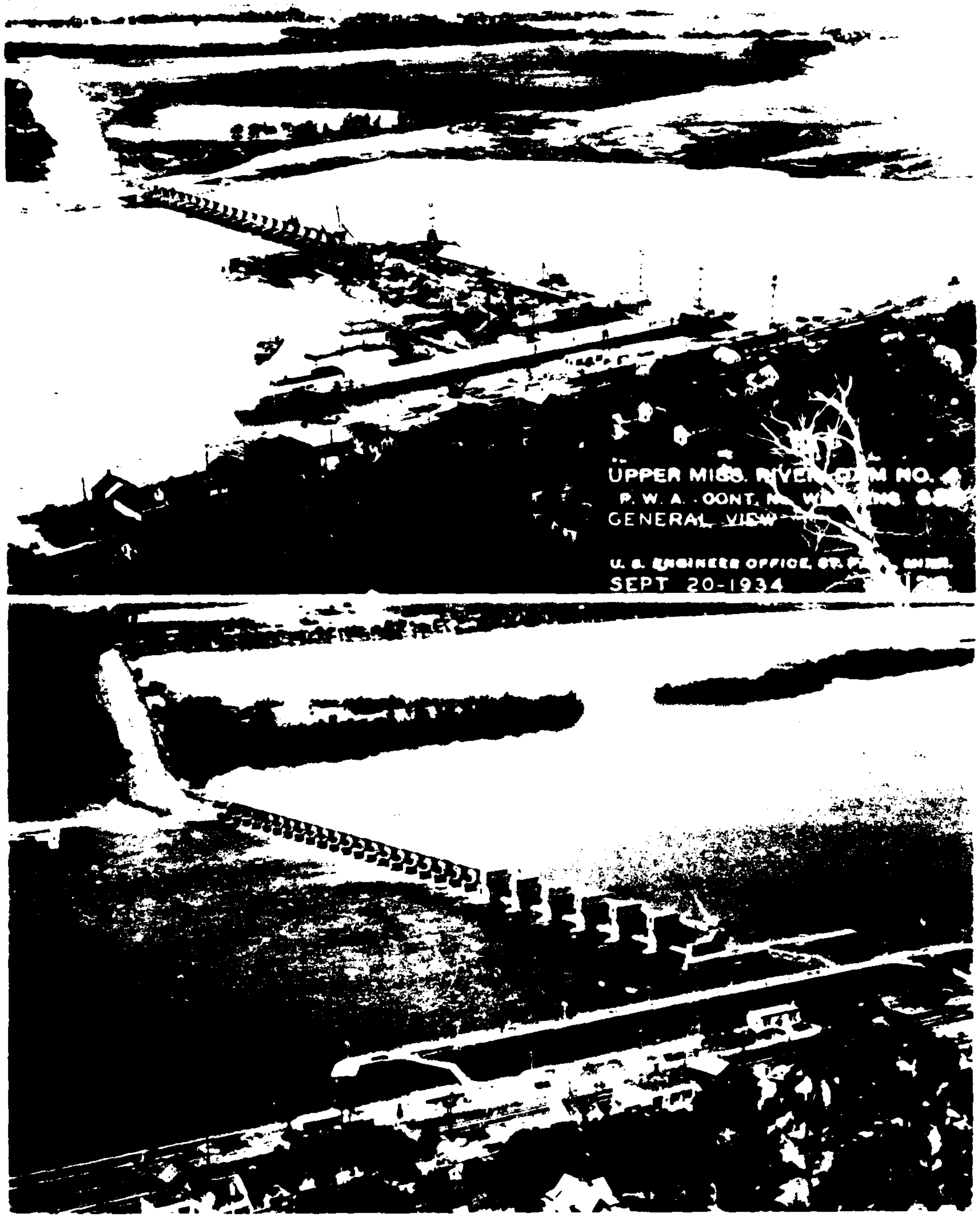


Figure 6 . The upper photograph shows Lock and Dam 4 during construction with its pool not filled. The lower photograph shows the completed dam and the filled pool in 1973.

special rights lands of the Department of the Interior. The fee title lands include 7,553 acres which were approved and granted by General Plans and Cooperative Agreement to the Department of the Interior, Bureau of Sport Fisheries and Wildlife for the conservation, maintenance and management of wildlife and wildlife habitats in connection with the National Migratory Bird Management Program. Special rights lands are those purchased by the U.S. Department of the Interior for the Upper Mississippi River Wildlife and Fish Refuge.

The Lock and Dam unit which controls water levels consists of a 1,619-foot movable crest dam containing a battery of 28 tainter gates and a series of 6 roller gates, one navigation lock 600 feet long and 100 feet wide, an uncompleted auxiliary lock and an earth dike 18,219 feet long. In Pool 5 there are 125 rock and willow wing dams and 9.65 miles of rip-rap bank works. The lock is closed by a pair of miter gates and the level is changed 9 feet by gravity flow through filling and empyting ports by a system of valves and pipes. Pool elevation is maintained at 660 feet above mean sea level (1912 Adjustment) by the 34 gates mentioned above. The site also includes two residences for personnel, lock house, equipment buildings, an access road, overhead walkway and observation deck for visitors to view locking operations.

Lock and Dam 5A, River Mile 728.5, Winona, Minnesota was placed in operation on July 6, 1936. The pool formed extends 9.6 river miles upstream from this point, or to mile 738.1.

A total of 6,910.09 acres of the pool is owned by the United States

Government. Of this land, 3,915.44 acres are fee title lands, 1,798.39 acres are flowage easement lands and 1.195.56 acres are special rights lands of the Department of the Interior. Seven tenths of an acre is leased from BNRR.

The fee title lands include 3,885 acres which were approved and granted by General Plans and Cooperative Agreements to the Department of the Interior, Bureau of Sport Fisheries and Wildlife for conservation, maintenance and management of wildlife and wildlife habitat. Special rights lands are those purchased by the Department of the Interior for inclusion in the Upper Mississippi River Wildlife and Fish Refuge.

The lock and dam unit controlling water levels consists of a 682-foot movable crest dam containing one battery of 5 tainter gates and a series of 5 roller gates, one navigation lock 600 feet long and 100 feet wide, an uncompleted auxiliary lock, and an earth dike 20,553 feet in length. A 1,000-foot concrete spillway is located in the earthen dike at a fixed elevation of 651 feet above sea level. The spillway contains a notch to pass water continuously to freshen the slough below. The lock is closed by a pair of miter gates and the level is changed 5½ feet by gravity flow through filling and emptying ports by a system of valves and pipes. Pool elevation is maintained at 651.0 feet above mean sea level (1912 Adjustment) by the 10 gates mentioned above. This site also includes two residences for personnel, lock house, equipment buildings and an access road. In Pool 5A there are 102 rock and willow wing dams and 7.5 miles of rip-rap bank works.

Lock and Dam 6, River Mile 714.3, Trempealeau, Wisconsin was placed in operation on June 30, 1936. The pool formed extends 14.2 river miles upstream from this point, or to mile 728.5.

A total of 4,022.03 acres of the pool is owned by the United States Government. Of this land, 326.41 acres are fee title lands, 2,225.63 acres are flowage easement lands and 1,362.81 acres are special rights lands of the Department of the Interior.

The fee title lands include 325 acres which were approved and granted by General Plans and Cooperative Agreements to the Department of the Interior, Bureau of Sport Fisheries and Wildlife for conservation, maintenance and management of wildlife and wildlife habitat. Special rights lands are those purchased by the Department of the Interior for inclusion in the Upper Mississippi River Wildlife and Fish Refuge.

The lock and dam unit controlling water levels consists of a 893-foot movable crest dam containing a battery of 10 tainter gates and a series of 5 roller gates, one navigation lock 600 feet long and 100 feet wide, an uncompleted auxiliary lock and an earth dike 3,050 feet long. A 1000-foot concrete spillway is located in the earthen dike. The elevation of the spillway is 645.5 feet above sea level. Two notches are provided to pass water continuously to freshen slough water below. In Pool 6 there are 104 rock and willow wing dams and 6.25 miles of rip-rap bank works. The lock is closed by a pair of miter gates and the level is changed 6.5 feet by gravity flow through filling and emptying ports, by a system of valves and pipes. Pool elevation is 645.5 feet above sea

level (1912 Adjustment) by the 15 gates mentioned above. The site also includes two residences for personnel, lock house, equipment sheds, an access road and observation deck for visitors to view locking operations.

CORPS OPERATION AND MAINTENANCE

Locks and Dams 4, 5, 5A and 6 of the Upper Mississippi 9-foot Channel Navigation Project were designed to provide a minimum depth of 9 feet for navigation. In order to continuously provide this depth, programmed operations of each lock and dam are followed, together with annual maintenance dredging of the navigation channel where accumulated sediment hinders passage of vessels requiring 9-foot draft.

Since the operations of the locks and dams are generally similar in the 9-foot project, there follows here a presentation of factors common to the four installations listed above. To accomplish the objectives of the project, the noveable section of the dams consists of tainter gates or roller gates or a combination of both, and earth dikes and fixed-elevation overflow spillways where required. The low dam elevations and small pool capacities relative to flood volume precludes operation of the dams for power production or flood control. The dams back up the water during periods of low flow and provide the required depths for navigation, but are opened wide during periods of high flow so as not to contribute to periods of flooding. Complaints are often registered when high stages occur in the navigation pools, but high water is caused by natural conditions and not by the operation of the dams. All the gates in each dam are removed from the water long before flood stage is reached so that natural

open river conditions exist during the flood period.

Whenever flooding threatens in the Mississippi River valley because of high water content of the winter's accumulation of snow, many people believe that the navigation pools should be drawn down to provide storage capacity for the coming floodwaters. However, there are two reasons why this drawdown cannot be performed, one legal and one technical. The legal reason is the so called "Anti Drawdown Law". The act of Congress dated 10 March 1934 entitled "An act to promote the conservation of wildlife, fish and game, and for other purposes", as amended by Public Law 732 on 14 August 1946 was amended by Public Law 697 on 19 June 1948 to include the following new section:

"Sec. 5A. In the management of existing facilities (including locks, dams and pools) in the Mississippi River between Rock Island, Illinois, and Minneapolis, Minnesota, administered by the United States Corps of Engineers of the Department of the Army, that Department is hereby directed to give full consideration and recognition to the needs of fish and other wildlife resources and their habitat dependent on such waters, without increasing additional liability to the Government, and, to the maximum extent possible without causing damage to levee and drainage districts, adjacent railroads and highways, farmlands, and dam structures, shall generally operate and maintain pool levels as though navigation was carried on throughout the year."

The technical reason for not drawing the pools down is the fact that the storage capacity of the navigation pools is so small in comparison

with the magnitude of the flood flows that a drawdown would be refilled in a matter of hours and would not appreciably lower the stages reached by the flood.

The outflow from each dam and elevation of each pool are dependent upon the inflow into the pool. There are two methods for estimating the inflow into the system. One method is based on converting rainfall directly into runoff and routing the latter through the system. The second method is to obtain the discharge at rated warning stations on the Mississippi River and on each main tributary. The latter method has been found to be more advantageous and is therfore the plan adopted by the St. Paul District. Reference is made to the inclosed District Map, figure , on which are shown the warning stations and locks and dams. Warning stations are generally established at locations that are ½ to 1 day's travel time above the mouths of tributary streams. On the larger tributaries, additional warning stations have been established, providing several days warning of approaching flows. Data from these stations are received from several agencies, including the U. S. Weather Bureau, U. S. Geological Survey, and several power companies, particularly the Northern States Power Company. Allowing proper time lag, these inflows are routed through each pool, making it possible to forecast daily the total inflow into each pool in the District.

When there is no flow in a pool contained by a lower dam, the water surface of the pool is level throughout its entire length. As the discharge entering the pool upstream increases, the upstream water level rises

creating a slope in the pool. Project pool elevations are maintained at the control point, usually near the middle of the pool, and the water level at the lower dam is allowed to fall as the discharge from the upper dam increases. This continues until the maximum allowable drawdown elevation for the pool is reached at the lower dam. The drawdown at the lower dam of the pool must be limited, however, so that navigation and conservation interests in the area will not be damaged by extremely low water levels.

Thus, the water surface profile of the pool will tend to pivot about the control point as the flow in the pool varies. This pivot point, called the "primary control point", is at or near the intersection of the project pool elevation and the ordinary high water profile. Court decisions have defined the ordinary high water mark as that point up to which the presence and action is so continuous as to destroy the value of the land for agricultural purposes by preventing growth of vegetation. On navigable lakes and rivers the Federal Government holds easement to use the riparian lands up to the ordinary high water mark in the public interest.

When maximum drawdown is achieved, control of pool water level is shifted to the dam, and the pool is then said to be in "secondary control". While in secondary control, the maximum drawdown elevation is maintained at the dam by increasing the discharge if the inflow increases. The water level at the primary control point and at all other points in the pool is thus allowed to rise. When the difference in water level at the lower dam

has been reduced to less than one foot (pool elevation minus tailwater elevation) during floods, the gates are raised completely out of the water, and open river flow is in effect. This process is reversed as flood waters subside.

The principal reasons for using this method of controlling the pools is that only the area between the control point and the lower dam will be inundated by the operation of the dam by the Corps. This greatly reduces the cost to the Government for acquiring flowage rights.

A priority system for vessels locking through has been established by the Secretary of the Army, as follows:

1. U. S. military vessels
2. Vessels carrying U. S. mail
3. Commercial passenger ships
4. Commercial tows
5. Commercial fishing boats
6. Pleasure boats

The Reservoir Regulating Section of the St. Paul District is composed of 3 hydraulic engineers and 4 engineering technicians. This section directs the operation of the Mississippi River navigation projects and is a part of the Hydraulics Branch which in turn is a part of the Engineering Division.

All of the locks and dams have short-wave radio receiving and transmitting equipment, and the District Office station is located on the site of

Lock and Dam No. 2 at Hastings, Minnesota. Each weekday the District Office radio station calls the Reservoir Regulating Section at 8 a.m. by telephone and connects the section with the district radio network, and all lockmasters from Lock and Dam No. 2 through Lock and Dam No. 10 are contacted directly. The regulating engineer plots pool, tail water and control point stage hydrographs from the incoming data and determines the daily orders for gate operation and pool range for each project. An engineering aide records the incoming data and the daily orders to the lockmasters and after the calls have been completed, he computes the inflows and storage in each pool and routes the flows through the entire St. Paul District. In this manner, it is possible to accurately estimate each day's operation, and to obtain a reasonably close estimate for longer periods of time.

In Pool 4, the channel is maintained at a depth of at least 9 feet. Current velocity is about 1 mph during normal stages and about 4 mph at high stages. The pool includes Lake Pepin which is formed behind the delta of the Chippewa River.

Project pool elevation of 667 is maintained at the primary control point, River Mile 760.4. The pool is considered in "secondary control" when the water elevation reaches 666.5 ± .2 foot. At a flow of about 88,000 cfs the river is termed to be in open river flow and the dam is out of control, with all gates out of the water. Main sources of inflow to the Mississippi River in Pool 4 are the Chippewa River at River Mile 763.4, the Cannon River at Mile 793, and the Beef River at Mile 755.

The Chippewa River is the greatest single source of sediment entering the main stem in Pool 4 and the influence of these sediments are felt a great distance downstream. Much dredging at the mouth of the Chippewa is required yearly to maintain project depth. Warning stations for gauging inflow into Pool 4 are located on the Cannon River. The Chippewa and its tributaries and the Beef River.

In Pool 5, the channel is maintained at a depth of at least 9 feet. Current velocity is about one mph. during normal stages and about 3 mph. at high stages. No bridges cross this pool.

Project pool elevation of 660 feet is maintained at the primary control point at Mile 748.5. The pool is considered in "secondary control" when water elevation reaches 659.5 $\pm$ .2 feet. At a flow of about 108,000 cfs., the river is said to be in open river flow and the dam is out of control with all the gates out of the water.

The Zumbro River at Mile 750 and the Whitewater River at Mile 744 are the main sources of inflow to Pool 5. Neither are great sources of sand but are dark with colloidal suspension. Warning stations for gauging inflow into Pool 5 are located on the Zumbro and Whitewater Rivers.

In Pool 5A, the channel is maintained at a depth of at least 9 feet. Current velocity is about one mph. during normal stages and about 3 mph at high stages. No bridges cross the pool. The Corps of Engineers' Boat Yard is located at Fountain City Bay (Mile 733.0), a short distance above Fountain City, Wisconsin.

Project pool elevation is maintained at Mile 737.9 the tailwater level at L/D 5. The pool is considered in "secondary control" when water elevation reaches 650 $\pm$ .2 feet. At a flow of about 58,000 cfs, the river is said to be in open river flow and the dam is out of control with all the gates out of the water. There are no sources of major inflows to Pool 5A, though two creeks, Garvin Brook and the Waumandee in Wisconsin do contribute. There is no significant contribution to the sediment load of the river entering this pool.

In Pool 6, the channel is maintained at a depth of at least 9 feet. Current velocity is about one mph. during normal stages and about 3 mph at high stages. Three bridges exist in this pool controlling horizontal and vertical clearance for navigation vessels.

Project pool elevation is maintained at the primary control point, Mile 725.69. The pool is considered in "secondary control" when water elevation reaches 644.5 $\pm$ .2 feet. At a flow of about 75,000 cfs, the river is said to be in open river flow and the dam is out of control with all the gates out of the water. The major source of inflow to Pool 6 is the Trempealeau River, Mile 717, but this is no great source of sand.

The City of Winona, Minnesota centered on Mile 726 in the past had contributed considerable waste water through its averaged and inefficient sewage disposal plant. This condition has imporved considerably with the opening of the new sewage treatment plant in 1972.

CHANNEL MAINTENANCE

In order to maintain the 9-foot depth for navigation, the pools formed by the lock and dams were considered to be the foremost feature. The slack water, however, reduced the velocity of the river, thus causing the settling out of sediment. Prior to the 9-foot channel project, the maintenance of lesser depth channels depended primarily on wing and closing dams to constrict the waters to the main channel, thus increasing water velocity and causing a continual scouring which maintained the navigable depth with a minimum of dredging.

The establishment of the 9-foot channel project facilities, however, raised water levels in most reaches of the river, but was not sufficient to provide the depth needed throughout its length. Thus, in areas where there was less depth than programmed for, it was necessary to dredge. The channel deepening is accomplished by using a hydraulic suction dredge and discharging to channelside higher ground through pipes floated on pontoons. The Corps of Engineers' dredge "William A. Thompson" performs this function on the Upper Mississippi.

POOL 4

Maintenance dredging has been necessary in 21 of the 44.1 river miles in this pool. Since dredging began in 1938, the Corps of Engineers has removed an average of 487,836 cubic yards annually. A total of 16,098,583 cubic yards has been dredged in Pool 4. There are four areas of high yardage removal identified from dredging records of the St. Paul District (Fig. 7-9). These are mile 789-796 (below Lock and Dam 3 and the mouth of the Cannon River), mile 784-785 (at the head of Lake Pepin where the

effects of the deep lake cause increased dropping of suspended sediments), mile 762-763 and 757-760 (both less than 6 miles below the mouth of the Chippewa River).

A survey made in 1968 by personnel of the Upper Mississippi River Wildlife and Fish Refuge, showed that there were 2.2 square miles of sandbar surface area resulting from natural deposits of sediment and/or maintenance dredging. This is only in the reach of the pool below the mouth of Lake Pepin, so the figure would be higher if the areas of sand deposit above Lake Pepin to Lock and Dam 3 were included. The sand deposits, if natural, are usually the effect of wing dams causing eddies, resulting in sediment dropping and filling the areas immediately downstream from the dams. The spoil from the hydraulic dredge is often placed on top of the bars which were formed behind the wing dams, and also on channelside river banks or shallow marsh areas within the 1600 foot maximum reach of the discharge pipe.

The disposal is made in the selected sites with no dikes, artifical devices, or other mean to contain the spoil within a define area. The configuration of the spoil pile is that of a cone with a cut off edge along the channel, fanning out on the back side. Pushing away sand from the end of the discharge pipe with a dozer may vary the resultant pile in heighth or breadth.

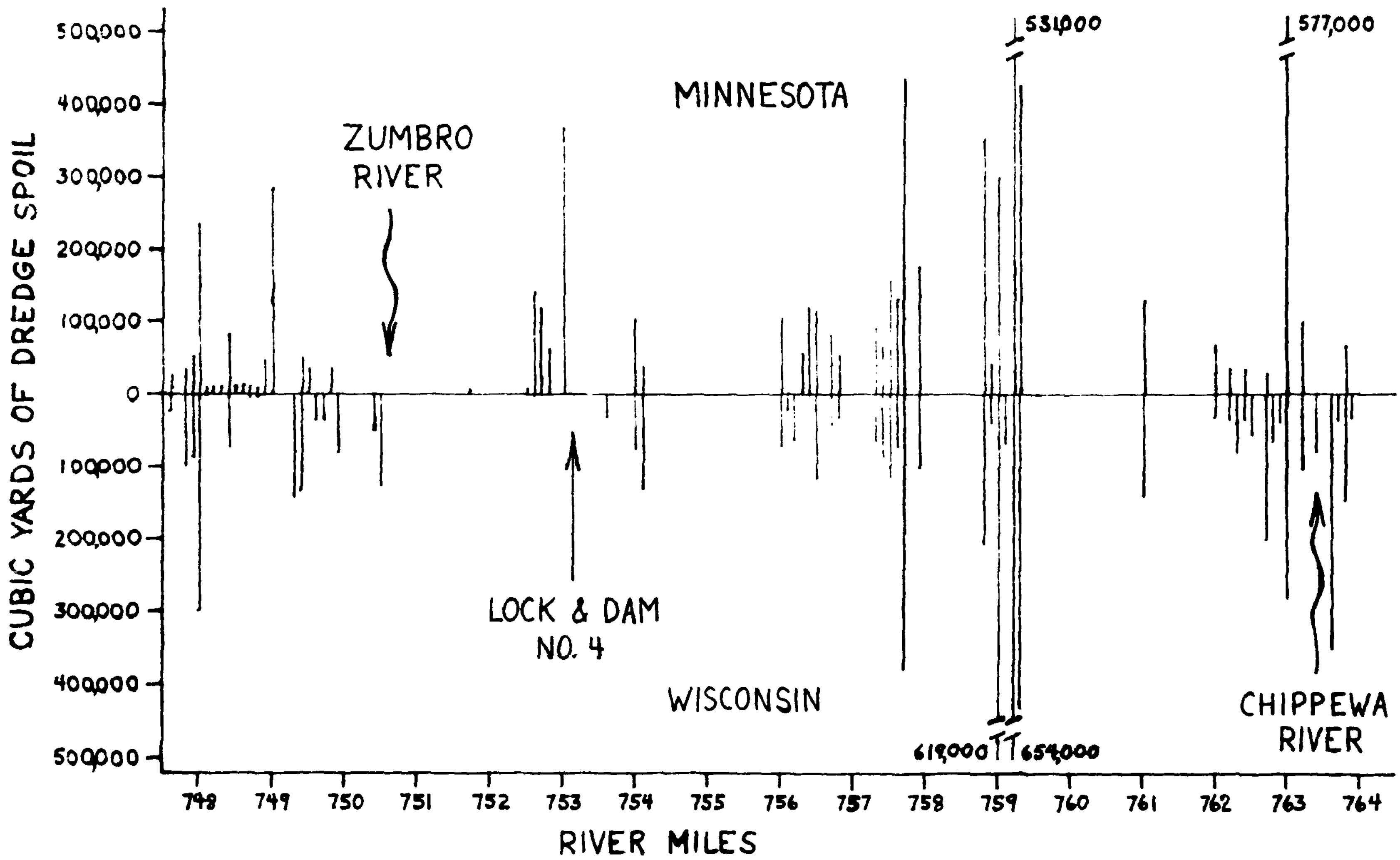


Fig. 7 . Total dredge spoil deposited along the main channel in Pool 4, 1936-1971.

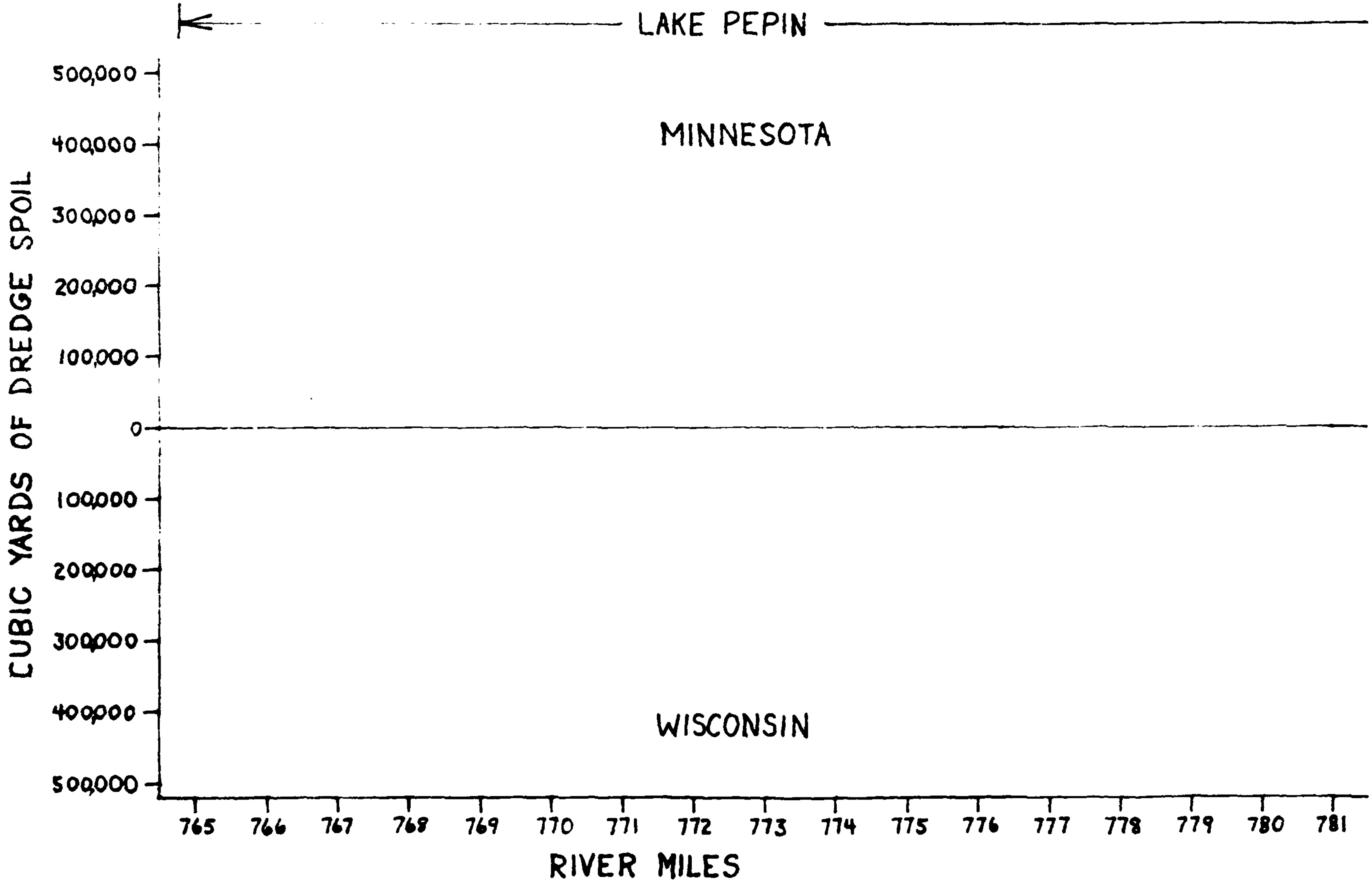


Fig. 8 . Total dredge spoil deposited along the main channel in Pool 4, 1936-1971.

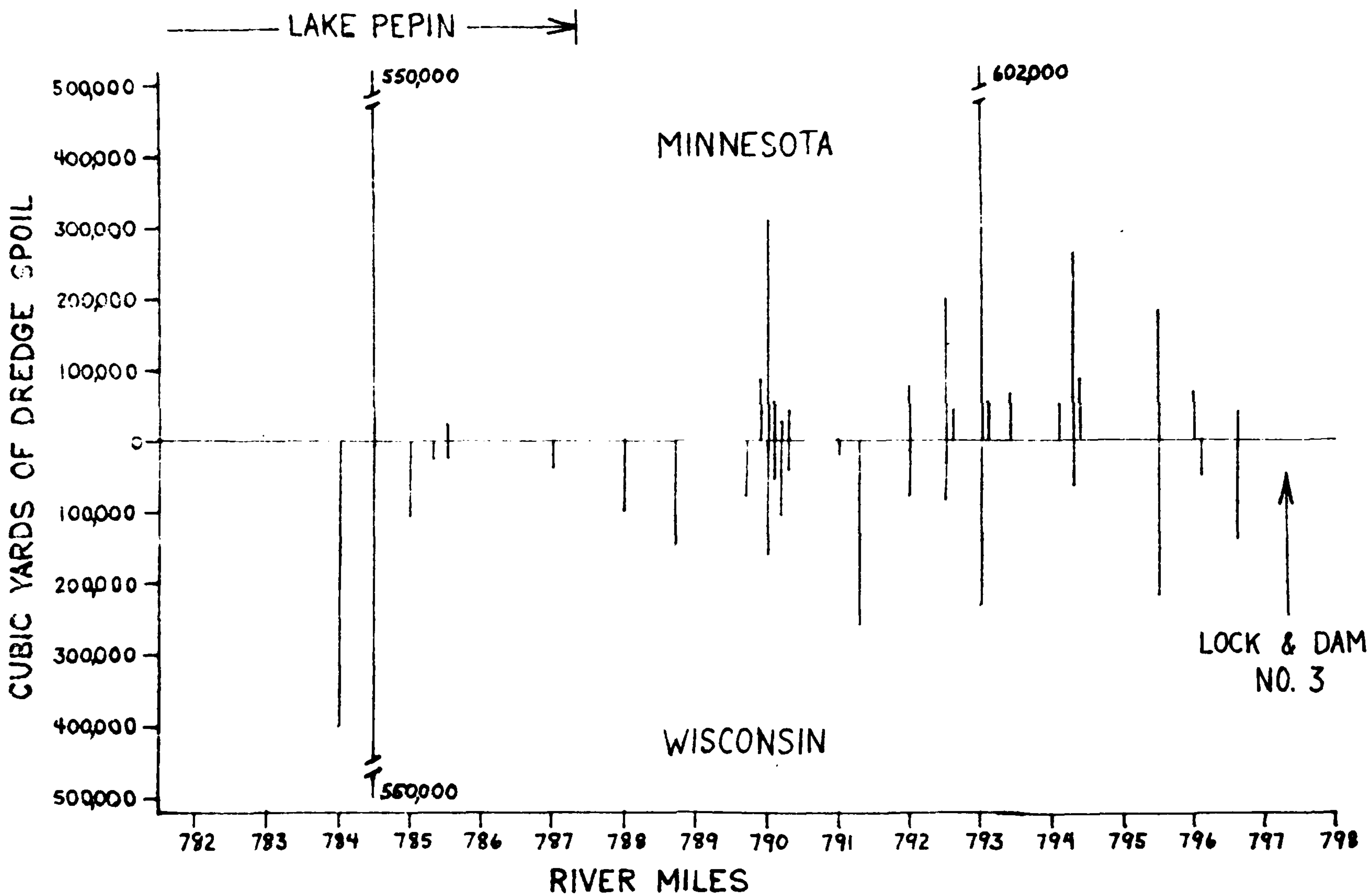


Fig. 9 . Total dredge spoil deposited along the main channel in Pool 4, 1936-1971.

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2. ENVIRONMENTAL SETTING

INTRODUCTION

The environmental setting of the project covered in this section is divided into (1) the natural setting and (2) the socioeconomic setting and includes a description of the study area from prior to the authorization of the 9-foot channel (1930) up to the present time. Actual construction on Lock and Dam 5 was finished in 1935. Thus, because the project under consideration was initiated about 40 years ago, it is difficult to reconstruct accurately the natural and socioeconomic setting which existed prior to lock and dam construction. There are three reasons for this difficulty:

1) lack of precise data on the environmental setting prior to 1930;
2) the difficulty in isolating some changes in the river environment due to the 9-foot channel from those caused by the earlier 4-1/2- and 6-foot channels or by increased population and industrialization along the river; and,
3) the practical emphasis on reducing the environmental impact of operating and maintaining the 9-foot channel assuming its continuation — not eliminating it entirely.

Therefore, the descriptions of the pre-project environmental settings in this section were reconstructed from available published information and are of necessity brief and not complete.

In the discussion of the environmental impact of the project later in Section 3 an attempt has been made to identify changes in the study area occurring in the past four decades that are attributable to the 9-foot channel project.

NATURAL SETTING

The most lucid early descriptions of the study area were those of Zebulon Pike (1811) who travelled through the study area in 1805 on an exploratory mission for the U. S. Government. His descriptions are important because they portray the appearance of the Mississippi River valley before it was modified by channelization projects or by other projects attributed to white men. On September 14, 1805, for example, Pike stood on a bluff top near Winona and described the scene below.

> "On the right we saw the mountains which we had passed in the morning, and the prairie in the rear, and, like distant clouds, the mountains at the Prairie de la Crosse. On our left, and under our feet, the valley between the two barren hills, through which the Mississippi winds in numerous channels, formed many beautiful islands, as far as the eye could embrace the scene. Our four boats under full sail, their flags streaming before the wind, formed altogether a prospect so variegated and romantic as one may scarecely expect to enjoy more than twice or thrice in the course of his life."

Upon reaching the sandy delta of the Chippewa, Pike camped and reflected upon the nature of the terrain that he had seen during the previous several days.

> "In the division of the Mississippi which we had passed from La Prairie des Chiens, the shores are more than three-quarters prairie on both sides, or, more properly speaking, bald hills, which instead of running parallel with the river, form a continual succession of high perpendicular cliffs and low valleys; they appear to head the river and to traverse the country in an angular direction. These hills and valleys exhibit some of the most romantic and sublime views I ever saw, but this

irregular scenery is sometimes interrupted by a wide extended plain, which brings to mind the verdant lawns of civilized regions, and would almost induce the traveller to imagine himself in the center of a highly cultivated plantation. The timber of this division is generally birch, elm, and cotton wood, all the cliffs being bordered by cedars.

The navigation, as far as the Iowa River is good, but from thence to the Sauteaux Chippewa River is very much obstructed by islands. In some places the Mississippi is uncommonly wide, and divided into many distant rivers, winding in parallel course through the same immense valley. But there are few sand bars in those narrow channels; the soil bring rich, the water cuts through it with facility."

Early channelization projects which were initiated in 1878 have been overshadowed by the 9-foot channel project of the 1930's. The navigation dams have transformed the Mississippi River, which was formerly a braided stream, into a series of large, well-fertilized, silted lakes through which an appreciable current still flows. The upper end of each pool (the tailwaters area) shows the river in relatively unmodified form. The mid-pool area consists of marsh which was formed when sub-marginal farm land and meadows were flooded by shallow water. The lower end of each pool is deep and essentially lake-like. The main stream of the river is punctuated by navigation markers and it is flanked in many areas by extensive deposits of dredge spoil. Railroad beds, highways, land fills and municipal flood dikes have constricted the flood plain in many areas.

Physical Aspects

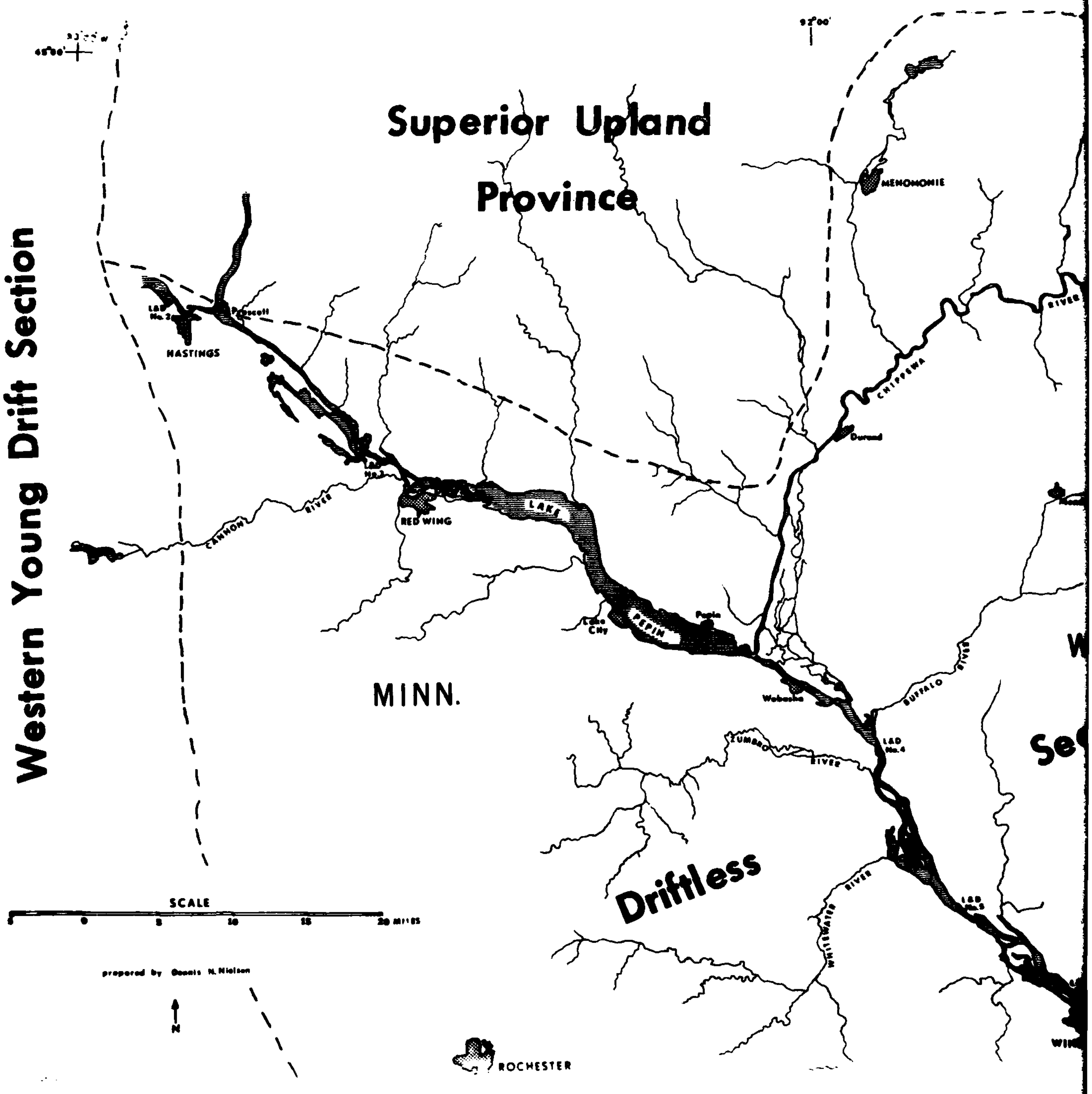
Regional Geology - prepared by Dennis N. Nielsen, Winona State College

Introduction The construction of a series of locks and dams on the Upper Mississippi River has resulted in many changes to the local and regional river environment. The changes have included geological as well as ecological and sociological changes. The geologic changes have had both a good and detrimental impact on the environment as this report will point out.

During this study it became difficult at times to determine geologic changes that have taken place subsequent to the construction of the lock and dams because very little previous geological work has been done in the Upper Mississippi River Valley. The glacial history is especially incomplete and warrants further investigation.

The content of this geologic report is intended to be used by the non-geologist and is thus written in more general terms than would be used in a detailed professional report. This report is concerned principally with the geology of Pools 4, 5, 5A and 6.

Physiography Although the total area drained by the Mississippi River above Winona is about 59,200 square miles, the study area during the summer of 1973 included only that area within or near the four pools described in this report (Fig. 10). Within this study area there are parts of three physiographic provinces each having a distinctive topographic and geologic setting. They include the Driftless Section of the Central



Superior Upland
Province
Western Young Drift Section
MINN.
Driftless
MENOMONIE
HASTINGS
Prescott
RED WING
LAKE
PEPIN
Pepin
Lake City
Wabasha
Durand
CHIPPEWA
RIVER
CANNON
RIVER
BUFFALO
RIVER
ZUMBRO
RIVER
WHITEWATER
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L&D No. 2
L&D No. 3
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SCALE
ROCHESTER
N

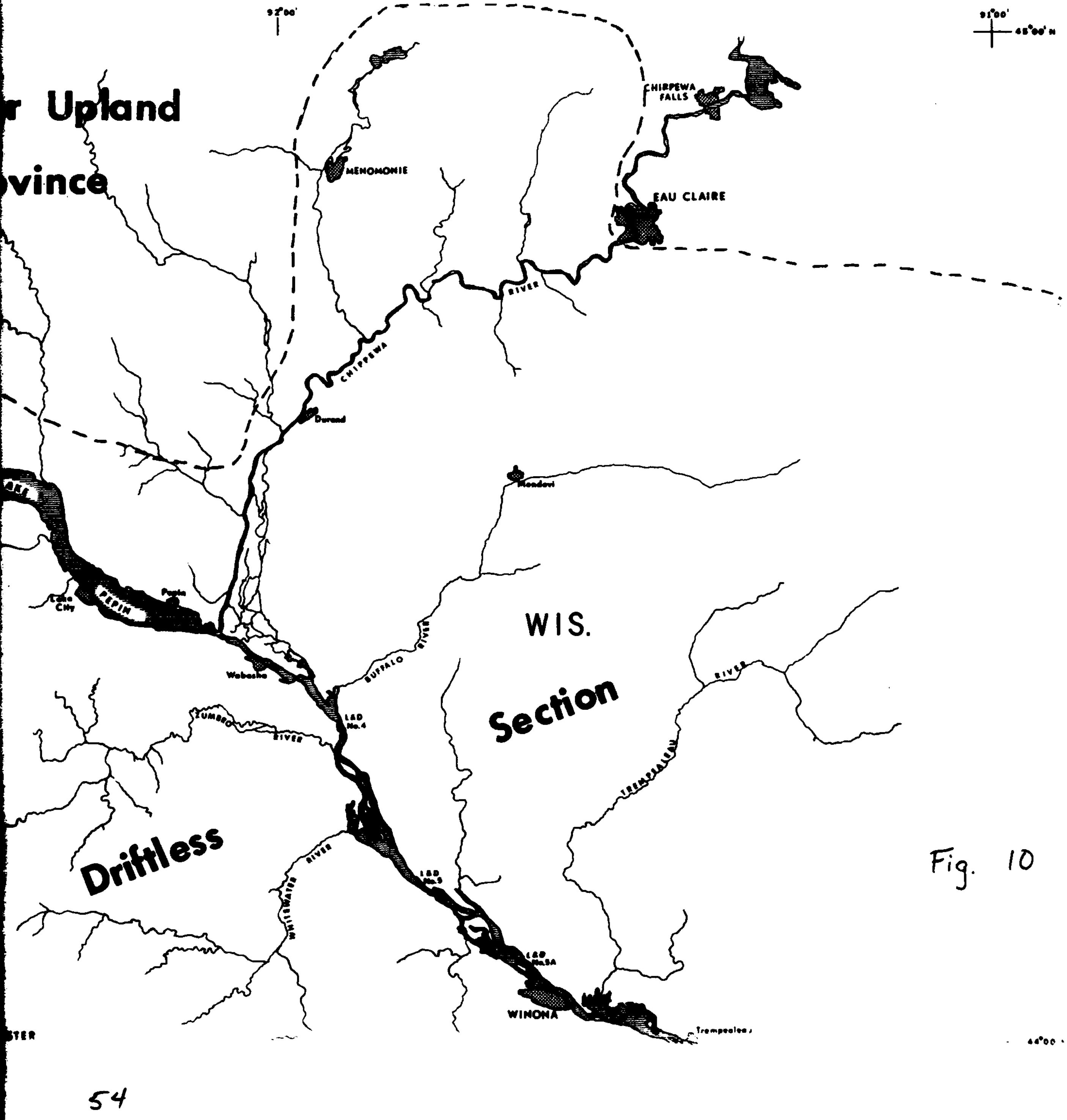
r Upland
vince
92°00'
91°00'
45°00' N
CHIPPEWA FALLS
MENOMONIE
EAU CLAIRE
CHIPPEWA
RIVER
Durand
Mondovi
PEPIN
Pepin
Lake City
Wabasha
BUFFALO RIVER
WIS.
Section
L&D No.4
ZUMBRO RIVER
TREMPEALEAU RIVER
Driftless
WHITEWATER RIVER
L&D No.5
L&D No.5A
WINONA
Trempealeau
44°00'
TER

Fig. 10

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Lowland Province East of the Mississippi, the Superior Upland Province and the Western Young Drift Section of the Central Lowland Province West of the Mississippi. Reference to each of these provinces or sections will be made throughout this report.

Central Lowlands Province - Two sections of this province are included in the Upper Mississippi River Basin; the Driftless Section and the Western Young Drift Section. The Driftless Section includes most of southwestern Wisconsin and parts of southeastern Minnesota and northeastern Iowa. It is called the "Driftless Section" because many geologists believe that the area was never glaciated during the recent ice age. Consequently, no glacial deposits (drift) occur in the area. The eastern boundary of this section is well marked by massive accumulations of glacial drift. The boundary between the Driftless Section and the Western Young Drift Section is complicated by a fringe of old, and much eroded drift, which extends nearly 40 miles west of the Mississippi River on the Iowa-Minnesota boundary. The boundary between the Driftless Section and the Superior Upland Province occurs where thin glacial drift overlies very old Precambrian Age rock.

The Western Young Drift Section has thick accumulations of glacial drift covering the surface to depths of several hundred feet. The preglacial rocks and sediments are thus buried and are difficult to study. This is in marked contrast to the Driftless Section where many preglacial rocks are exposed at the surface. The Driftless Section has greater topographic relief than the Western Young Drift Section. Thus, the

Western Young Drift Section has poorer drainage than the Driftless Section.

Superior Upland Province - This province occurs north of the Driftless Section and is coextensive with the Canadian Shield, an area of Precambrian rocks of all origins. Most of the Shield is composed of erosion - resistant crystalline igneous and metamorphic rocks. The Canadian Shield was worm down by millions of years of erosion to a relatively flat plain and was later buried in part, by a thin glacial drift cover. The Superior Upland is that part of the Canadian Shield that lies within the United States.

Drainage The Mississippi River within the study area (Fig. 10) has many tributary streams that influence the hydrology and geology of the area. Gauging stations operated by the United States Geological Survey are located on the important tributaries. The stations record stream discharge, stage, and water quality. Such information is usefull in determining the sediment transporting ability of the stream. A brief discussion of the tributaries occurs below starting with the tributary farthest upstream. The number following the name of each tributary is the official number of the U. S. Geological Gauging Station for the tributary.

Cannon River at Welch, Minnesota (5-3552) - The Cannon River at Welch, Minnesota drains an area of about 1,320 square miles. The average discharge of the river for the past 36 years is 475 cfs. The maximum discharge occured on April 8, 1965 when it reach 36,100 cfs. The minimum discharge occurred on January 3, 1950 when it was only 2.5 cfs.

Chippewa River at Durand, Wisconsin (5-3695) - The area of the

Chippewa River Basin above Durand is about 9,010 square miles. Station records over the past 37 years indicate that the average discharge of the Chippewa at Durand is 7,206 cfs. The maximum discharge occured on May 3, 1954 when it reached 101,000 cfs. On November 24, 1950 the maximum discharge of 1,020 cfs occurred. The flow of the Chippewa River is controlled to some extent by the many dams occurring along its course. From Durand to the mouth of the Chippewa River very little additional water enters the river. The Chippewa River is the largest tributary of the Mississippi in the study area.

Zumbro River at Zumbro Falls, Minnesota (5-3740) - The basin area above Zumbro Falls includes 1,130 square miles. The average discharge for the past 43 years is 476 cfs. The discharge reached a maximum of 35,900 cfs on July 22, 1951. A minimum of 27 cfs was recorded on January 12, 1935.

South Fork Whitewater River near Altura, Minnesota (5-3765) - The South Fork of the Whitewater River drains a small area of only 76.8 square miles. The average discharge over a period of 26 years is 27.3 cfs. The maximum discharge occurred on August 31, 1947 when it reached 5,460 cfs. The minimum discharge recorded was on March 24, 1940 when it was only 3.8 cfs.

Trempealeau River at Dodge, Wisconsin (5-3795) - The Trempealeau River Basin above Dodge has an area of 643 square miles. The river has had an average discharge of 388 cfs during the last 36 years. The maximum

discharge occurred on April 4, 1956 when it reached 17,400 cfs. The minimum discharge was measured on January 10, 1938 when it was only 98 cfs.

Bedrock Geology The tributary streams previously mentioned in this report carry sediment that is composed of bits and pieces of broken rock. The kind of rock supplying the sediment varies throughout the drainage basin. Thus, each tributary has an assortment of rock types in its sediment that is characteristic of the kinds of bedrock found within its basin area. A discussion of the kinds of bedrock and their distribution will thus be helpful in understanding the geologic history of the Upper Mississippi River basin.

Bedrock is exposed in some localities in the Upper Mississippi River basin where erosion has stripped away the surface sediments and soils. Most of the bedrock in the basin is covered by variable thicknesses of unconsolidated river, wind, swamp, lake, or glacier sediment deposited within the recent geologic past. If all the loose sediment (including soils) were stripped away from the basin, the bedrock could be seen. The type of bedrock and its distribution would be as shown in Figure 11.

Precambrian rocks are older than 600 million years and occur at the surface in some parts of the basin. Precambrian basic (dark) igneous rocks form the highlands in northeastern Minnesota and northwestern Wisconsin. These basic rocks are volcanic in origin. North-central Minnesota and Wisconsin is underlain by complex Precambrian igneous and

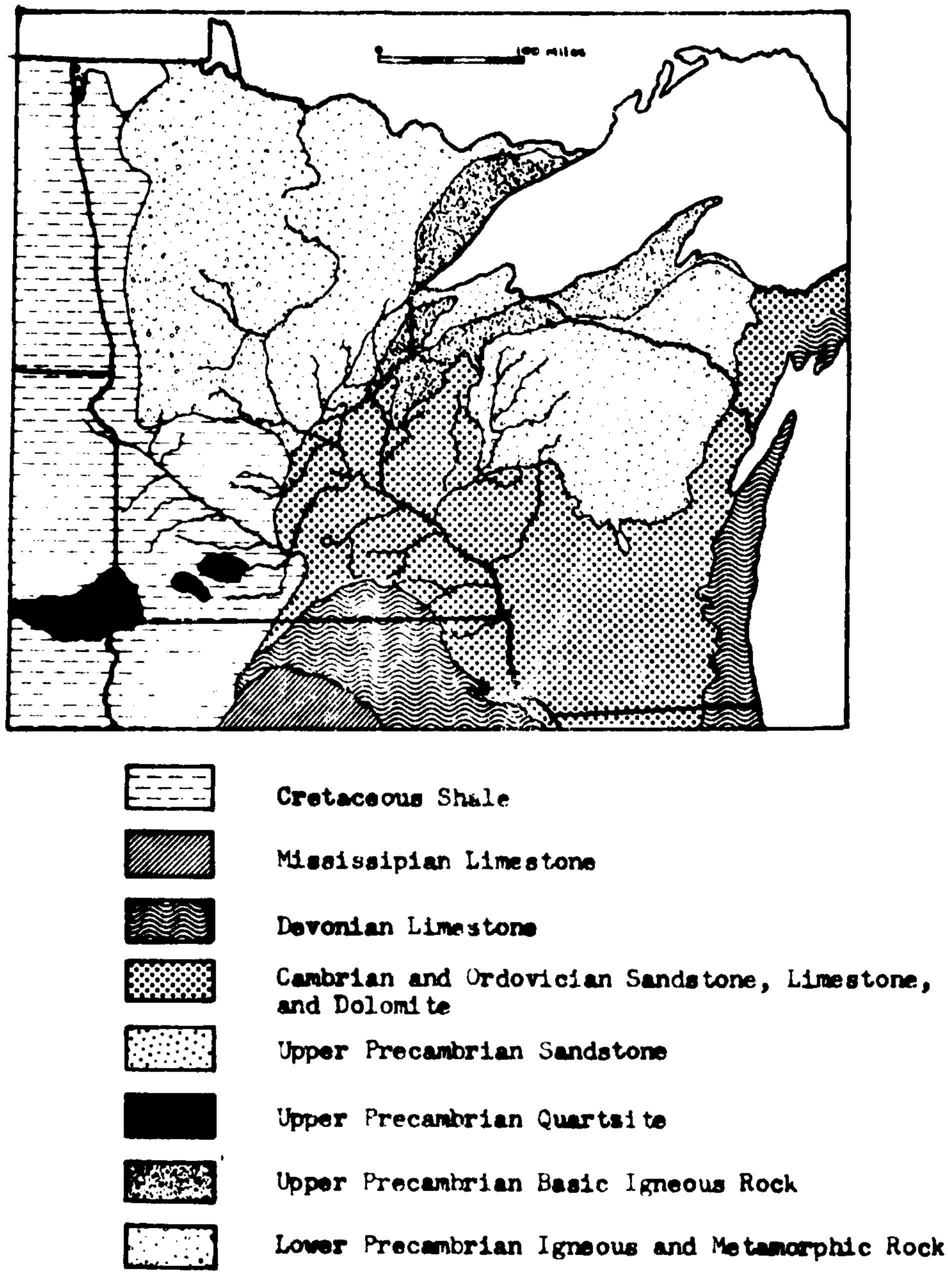


Figure 11. Geologic map of the Upper Midwest.

metamorphic rocks. These igneous rocks are not volcanic but were instead formed deep within the earth's crust and were later exposed by erosion and uplift. These igneous and metamorphic rocks include many kinds of granites found within the region. Upper Precambrian red sandstone occurs in a belt extending from northwestern Wisconsin southwestward into Minnesota.

Southeastern Minnesota and southwestern Wisconsin are underlain by relatively flat-lying Paleozoic sandstones and limestones. These rocks were formed from sediment deposited by successive marine inundations occurring between 400,000,000 and 600,000,000 years ago. The sediments were later compacted and cemented forming sedimentary rock. The sandstones have a combined thickness of over 400 feet. They typically are poorly cemented and are easily eroded. They have a high porosity and permeability and are thus important aquifers in the basin. The sandstones are usually overlain by massive limestone or dolomite rocks as much as 100 feet thick. The limestone and dolomite is more resistant to erosion and is found capping bluffs and cliffs. This is especially well seen along the bluffs of the Mississippi River between St. Paul and Guttenberg.

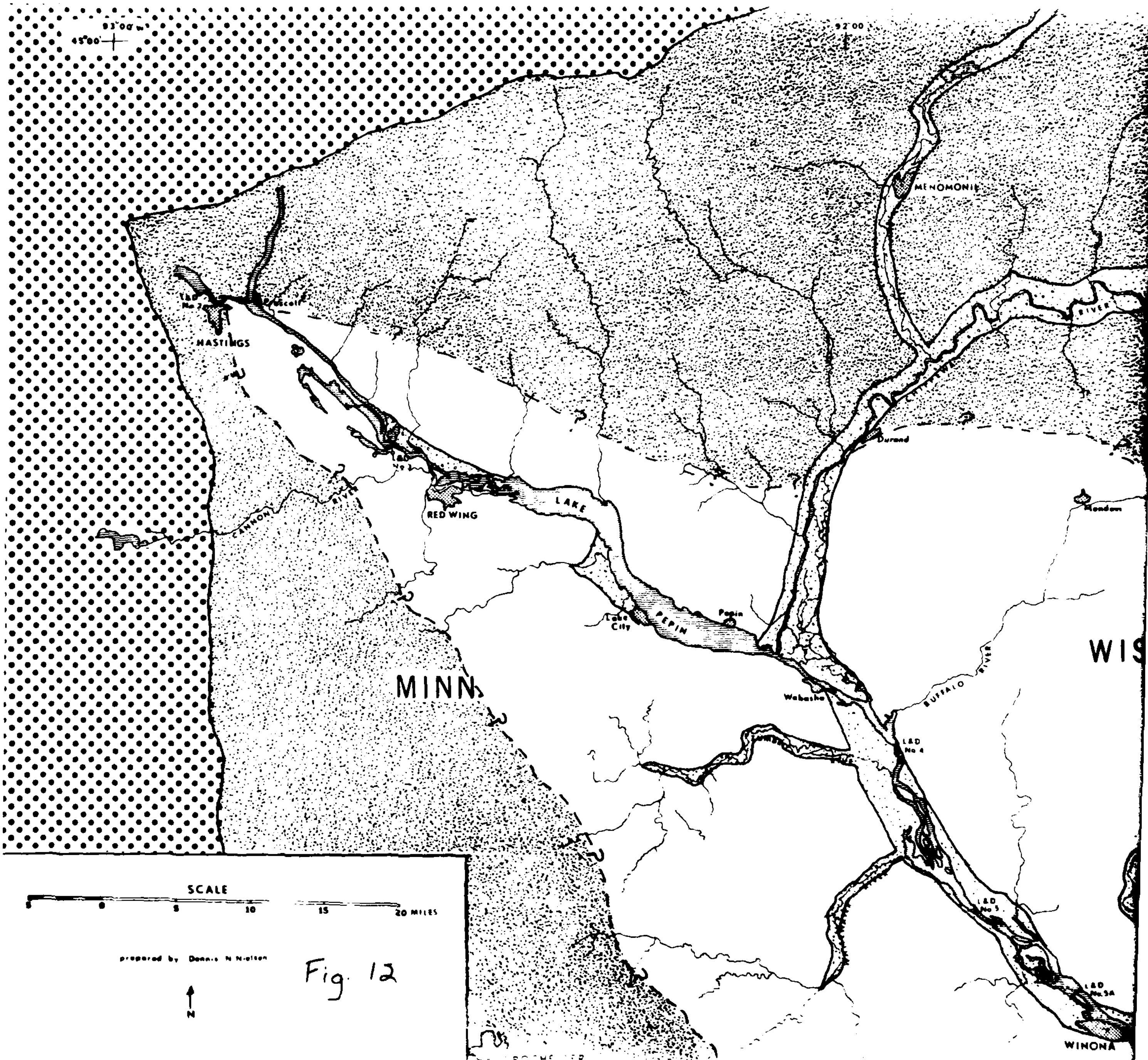
Southwestern Minnesota, northeastern South Dakota, and northwestern Iowa are underlain by Cretaceous shale. The shale was deposited by a sea that invaded the region about 80,000,000 years ago. The shale is thin and patchy and is easily eroded. Some small areas of Precambrian quartzites occur in the area also but are very resistant to erosion and are thus not an important source of river sediment.

Surface Sediment Although the bedrock geology determines the structural framework and to some extent the topography of the physiographic provinces, of equal importance in terms of land use are the unconsolidated surface deposits and soils. Figure shows the principal surficial deposits in the study area.

The Driftless Section is mantled with loess; a wind-blown silt deposit several tens of feet thick. The silt was eroded from glacial drift during the later part of the Pleistocene Ice Age. The soils developed on the loess are some of the finest agricultural soils in the United States. The loess is easily eroded and thus large amounts are eroded by streams each year.

The Superior Upland Province is mantled with a thin, discontinuous cover of glacial drift. The drift is composed of a mixture of gravel, sand, silt, and clay that was deposited directly from glacier ice with little or no sorting of grains by running water. Such drift is referred to as till. Some of the drift was eroded by running water resulting in sorting of the sediment (fines washed away). Such sediment is called glacial outwash and is composed of sand and gravel. Most of this province is forest covered and thus is not agriculturally important. Less sediment is washed into the streams draining this province because of the forest cover.

The Western Young Drift Section is covered by thick deposits of glacial drift including till and outwash. The region is agriculturally based resulting in significantly more stream erosion than in the Superior


93°00'
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MENOMONIE
HASTINGS
RED WING
LAKE
PEPIN
Lake City
Pepin
Durand
Wabasha
BUFFALO RIVER
MINN
WIS
L&D No 4
L&D No 5
L&D No 5A
WINONA
SCALE
0
5
10
15
20 MILES
prepared by Dennis N Nielsen
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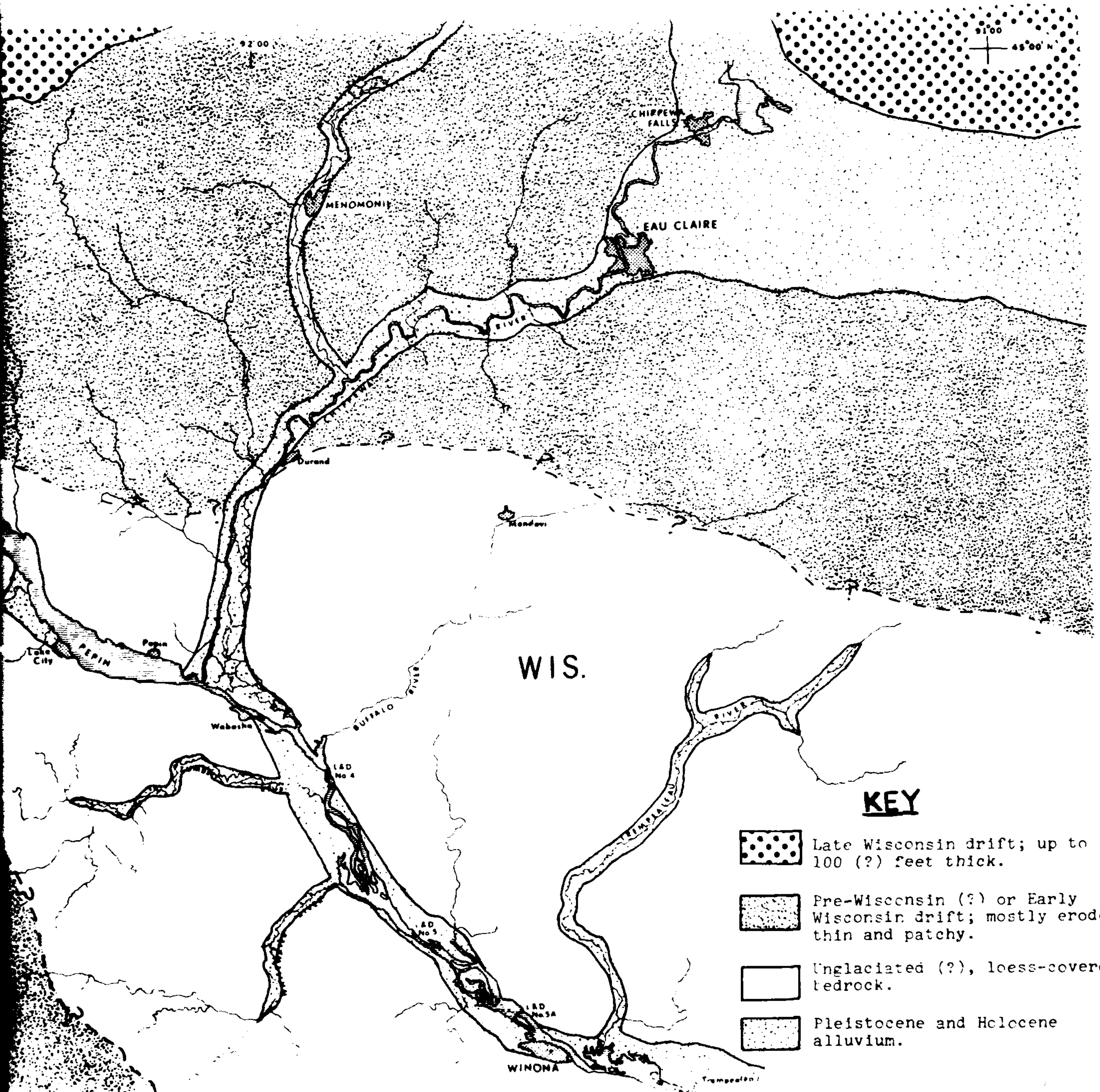
Fig. 12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CHIPPEWA FALLS
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EAU CLAIRE
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Durand
Mondovi
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Lake City
PEPIN
Pepin
Wabasha
BUFFALO RIVER
L&D No 4
L&D No 5
L&D No 5A
WINONA
RIVER
TREMPEALEAU
KEY
Late Wisconsin drift; up to 100 (?) feet thick.
Pre-Wisconsin (?) or Early Wisconsin drift; mostly erode thin and patchy.
Unglaciated (?), loess-coverc bedrock.
Pleistocene and Holocene alluvium.

2

62

Upland Province.

The Upper Mississippi River Valley and its many tributaries contain large quantities of river alluvium deposited during the Pleistocene. The alluvium is easily eroded and is often of commercial sand and aggregate quality.

Geologic History of the Upper Mississippi River

Preglacial History - Early investigators believed that the Minnesota Valley and the Mississippi Valley above the Ohio River formed since the deposition of glacial drift. Most recent workers, however, believe that the present drainage lines are for a large part, ancient ones formed millions of years before the Pleistocene Ice Ages. The variation in width of the Mississippi Valley is due to differences in hardness of the rocks intersected by the river. The occurrence of very old glacial drift in the bottom of the Whitewater River Valley suggests that the valley must have been there before glaciation.

The millions of years of preglacial erosion produced a well-integrated drainage system in the study area. The many tributary valleys of the Mississippi displayed in the Driftless Section were formed during this time. The drainage is so good that no natural lakes exist in the section except on the Mississippi floodplain. Geomorphologists would describe the drainage as being dendritic and the regional age would be sub-mature. In most of the tributary valleys good exposures of sedimentary rocks occur.

Glacial History - Beginning about 1,000,000 years ago the Upper Midwest entered what is commonly referred to at the Pleistocene Ice Age. The average world climatic temperature dropped at this time and a large continental glacier began to develop in the vicinity of Hudson Bay. It probably looked much like the Antarctic ice sheet we see today. The glacier continued to increase in thickness and lateral extent which eventually resulted in ice movement away from the center of accumulation. At its maximum, the glacier covered all of Canada east of the Rockies and extended as far south as the Ohio River.

The Pleistocene glaciation was not represented by a single advance of ice but was multiple in nature. The glacier built up and subsequently melted four times during the Pleistocene. Each glacial episode was separated by an interglacial period having a climate that was at least as warm as it is today. Each glacial and interglacial period is named after an area where the geologic history of that period is especially well displayed. The naming is as shown below.

Nebraskan Glaciation began about 1,000,000 years B.P.

Aftonian Interglacial

Kansan Glaciation

Yarmouthian Interglacial

Illinoian Glaciation

Sangamon Interglacial

Wisconsin Glaciation ended 10,000 years B.P.

Pre-Wisconsin Glaciation - Each glaciation is recorded by drift deposits that in many cases are buried by younger drift deposited by later glaciers. In the Western Young Drift Section many deposits of old drift have been found underlying young drift deposited during the Wisconsin Stage. It is difficult to determine the age of such old drift because radiocarbon dating methods are useless beyond 50,000 years.

Scattered pockets of old glacial drift occur as far east as Winona County. In addition, many erratic boulders can be found that were obviously transported by glacier ice. Some geologists think that the driftless area of Wisconsin and southeastern Minnesota was glaciated only during the Nebraskan Stage while others think it was a Kansan glacier that was responsible. Black (1959) believes that early Wisconsin glaciers covered the Driftless Section but deposited very little sediment. To date, the problem is as yet unresolved.

The pre-Wisconsin glaciers probably disrupted drainage in the Upper Mississippi River Valley as much or more than the Wisconsin glaciers. Unfortunately, the geologic evidence of such disruptions are either buried or were destroyed by later glaciers or postglacial erosion.

Wisconsin Glasiation in Minnesota - The Wisconsin Glaciation is the most recent glaciation and of the most importance in the Upper Mississippi River Valley. Wisconsin glacial drift covers nearly all of Minnesota, Wisconsin, and northern Iowa, except for the Driftless Section.

Most of the Wisconsin drift was deposited during the later part

of the stage between 10,000 and 20,000 years B.P. (before present). Most of the drift surface is poorly drained as indicated by the more than 10,000 lakes in Minnesota that are of glacial origin. Pre-Wisconsin river valleys were buried by glacial ice and in many cases were not reactivated following deglaciation. The course of the Mississippi above the junction with the Minnesota River probably does not follow its preglacial course but rather one developed at the close of Pleistocene.

The Wisconsin glaciation in Minnesota involved the interactions of four major ice lobes, from west to east the Des Moines, Wadena, Rainy, and Superior. Each lobe was localized by bedrock lowlands and characterized by distinctive rock types that reflect the bedrock geology of northern Minnesota and adjacent Canada. The history of the Wisconsin Stage in Minnesota can best be explained by subdividing the stage into five phases (Wright and Ruhe, 1965).

During the Hewitt Phase, the Wadena Lobe entered the shallow Red Lakes lowland of northwestern Minnesota from the northwest but was blocked by the contemporaneous Rainy Lobe (Fig. 13). The Wadena Lobe was diverted to the southwest and formed some elliptical-shaped hills of drift that are commonly referred to as drumlins. The Wadena Lobe terminated in the Alexandria area and deposited large amounts of drift paralleling the ice-margin. The drift forms a massive hilly landform called the Alexandria Moraine (Fig. 13).

During the St. Croix Phase, the Wadena Lobe retreated and formed the

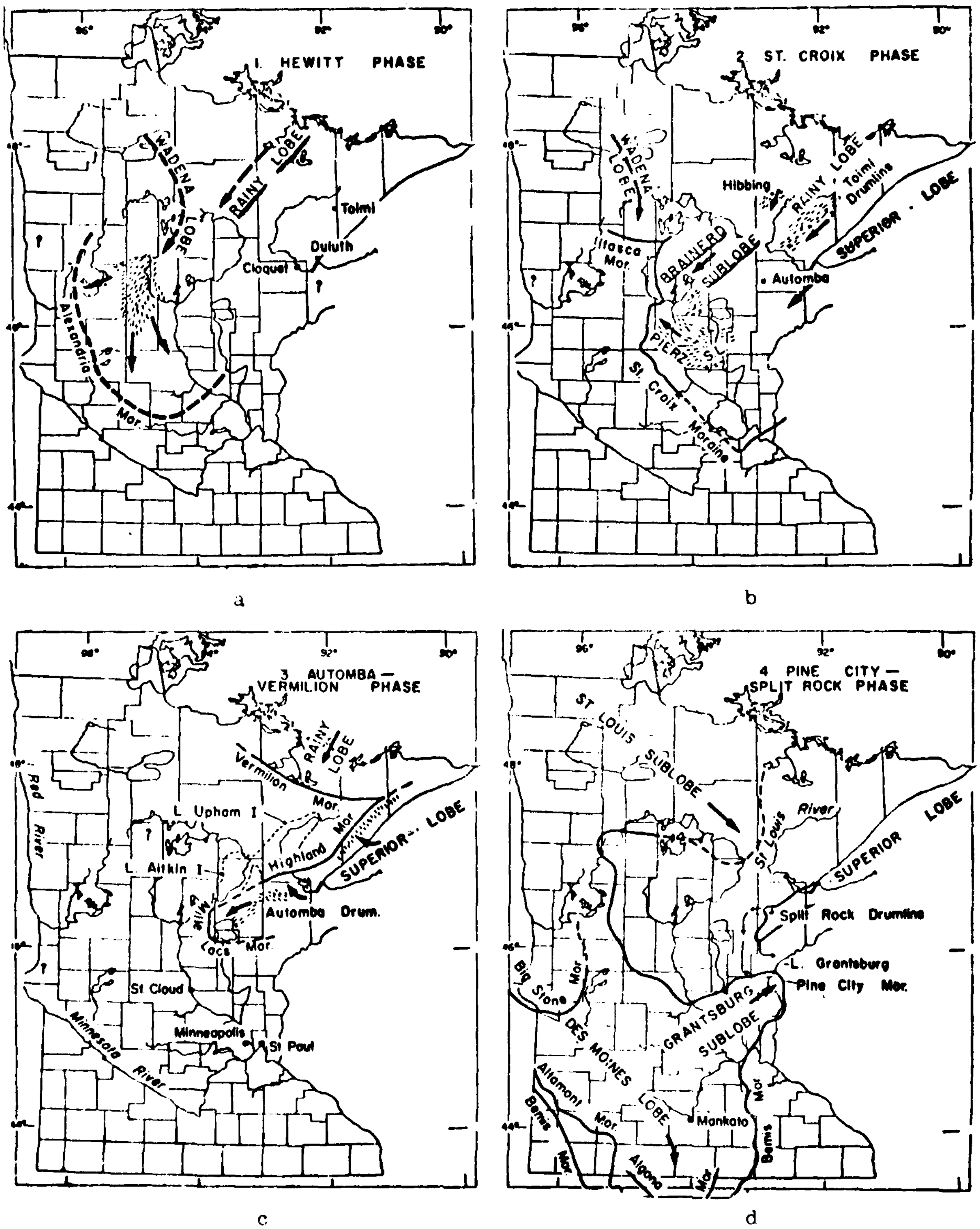


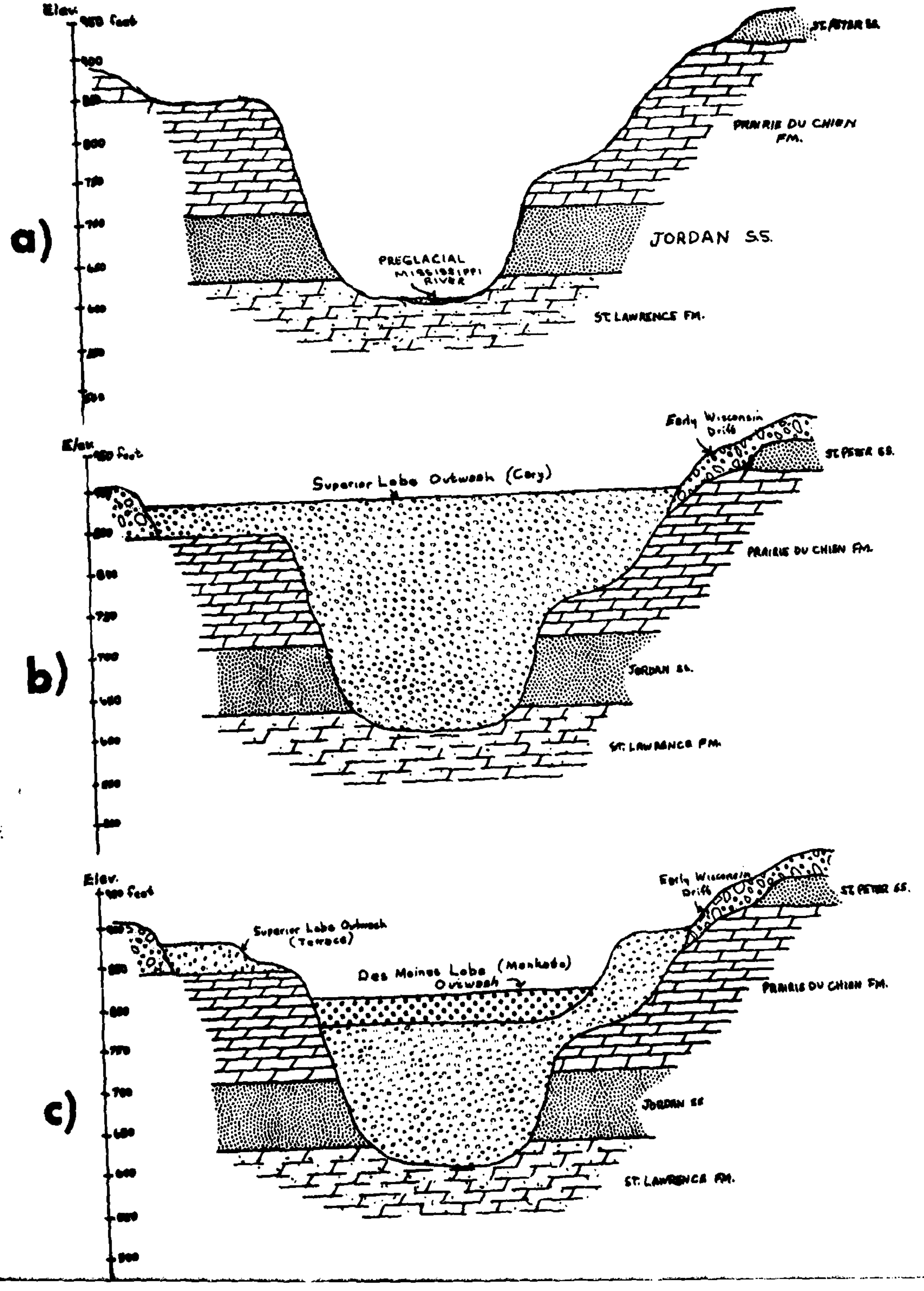
Figure 13. Hewitt, St. Croix, Automba-Vermilion, and Pine City-Split-Rock phases of Wisconsin glaciation in Minnesota (Wright & Ruhe, 1965).

Itasca Moraine, and the Superior and Rainy Lobes reached a common terminus at the St. Croix Moraine (Fig. 13). Great volumes of meltwater drained through the Mississippi Valley carrying a very high bed load. The amount of bed-load sediment was so great that the Mississippi Valley became filled with sand and gravel (Fig. 14). Matsch (1962) studied the sediment and found that there is a general gradation from boulder and cobble gravel upward to finer gravel and coarse sand, although every section contains interbeds of various texture. The sediment contains rocks derived from the Superior Upland Province such as granite, basalt, red felsite, and red sandstone.

The Superior and Rainy Lobe outwash has been greatly modified by subsequent stream action in the Mississippi Valley. Terrace remnants along the valley sides remain between elevations of 870 feet and 850 feet in the Prescott, Wisconsin area. The terrace surfaces are developed on deep fill in some places, and elsewhere they consist of relatively thin veneers on bedrock benches. Deposits below 750 feet are covered by younger sediment.

As deglaciation continued northward, the stream load was reduced resulting in trenching of the earlier deposits.

During the Automba-Vermilion Phase, the Rainy Lobe thinned and continued to retreat and eventually paused long enough to form the Vermilion Moraine (Fig. 13). During this time the Superior Lobe readvanced out of the Lake Superior Basin and formed the Mille Lacs Moraine and the


a)
Elev.
950 feet
JORDAN SS.
PRAIRIE DU CHIEN FM.
ST. PETER SS.
ST. LAWRENCE FM.
PREGLACIAL MISSISSIPPI RIVER
b)
Elev.
950 feet
Superior Lobe Outwash (Cary)
Early Wisconsin Drift
ST. PETER SS.
PRAIRIE DU CHIEN FM.
JORDAN SS.
ST. LAWRENCE FM.
c)
Elev.
950 feet
Superior Lobe Outwash (Terrace)
Des Moines Lobe (Mankato) Outwash
Early Wisconsin Drift
ST. PETER SS.
PRAIRIE DU CHIEN FM.
JORDAN SS
ST. LAWRENCE FM.

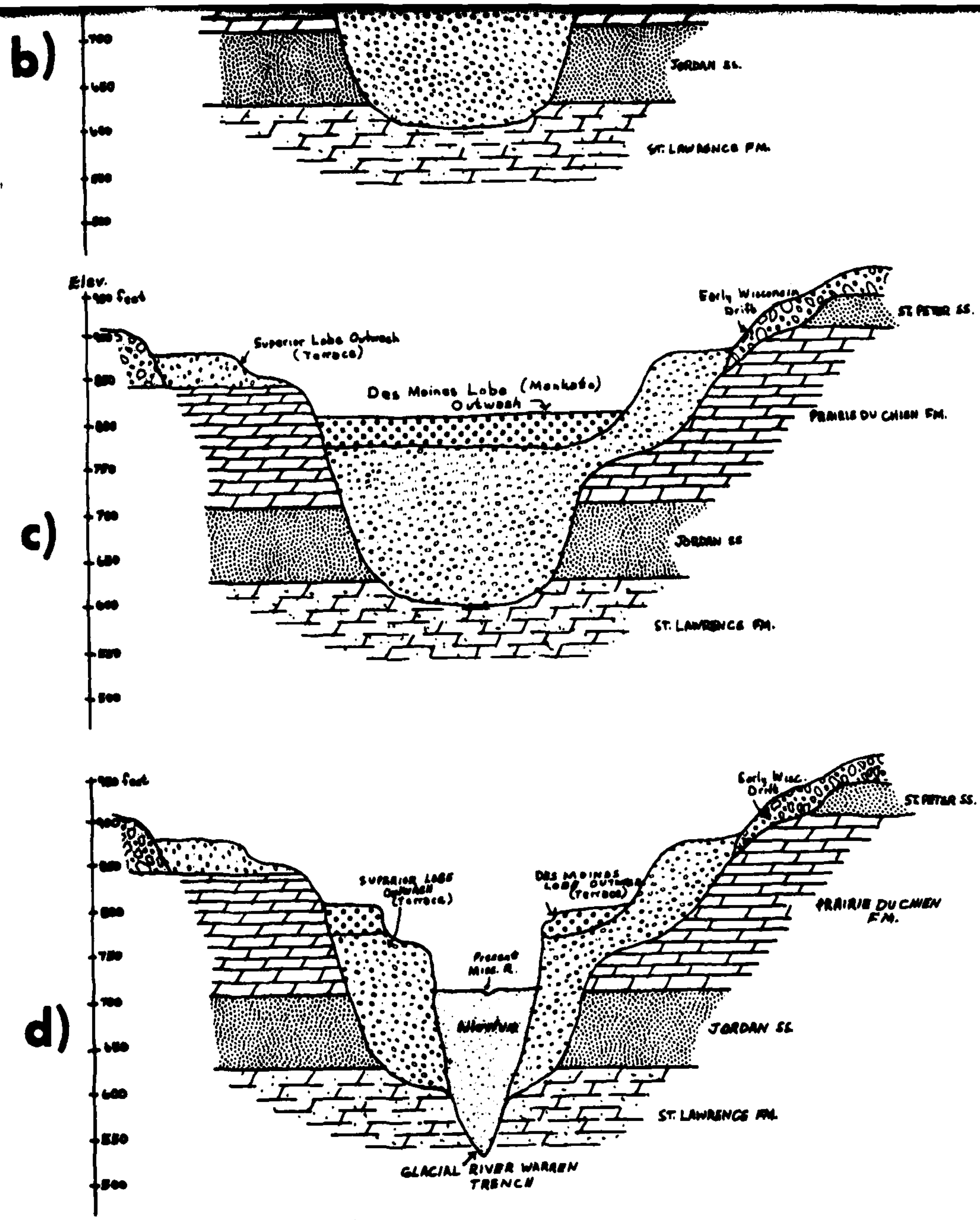


Fig. 14. Geological cross section of the Mississippi River Valley at Winona, Mn.

Highland Moraine. The Automba Drumlin Field was also produced during this readvance. The Superior Lobe blocked the drainage of the St. Louis River and produced glacial Lakes Upham I and Aitkin I (Fig. 13). Large quantities of melt water and outwash probably were carried in the Mississippi Valley during this phase.

By the end of the Automba phase the active Superior Lobe had retreated into the Lake Superior basin. The Split Rock Drumlin Field was produced by a slight readvance of the Superior Lobe (Fig. 13). The Des Moines Lobe advanced during this phase eventually reaching its terminus near Des Moines, Iowa. The Des Moines Lobe advanced over Cretaceous shale in southwestern Minnesota and incorporated much of it as part of its drift composition.

The Grantsburg Sublobe was formed from the Des Moines Lobe and advanced northeastward across the recent deposits of the Superior Lobe. It formed the Pine City Moraine at its terminus (Fig. 13). The Grantsburg Sublobe blocked all southern drainage thus forming glacial Lake Grantsburg. Some glacial melt water from the Des Moines Lobe and the Grantsburg Sublobe drained down the Mississippi and St. Croix Valleys (Fig. 13). The outwash sediment is noticeable rich in shale fragments and other rock types characteristic of western and southwestern Minnesota bedrock (Matsch, 1962). Today the outwash can be found in terraces along the Mississippi at elevations ranging from 820 feet at the junction of the Minnesota River to 790 feet north of Lake City.

The eastern terminus of the Des Moines Lobe reached Owatonna and dispatched great volumes of melt water and outwash that flowed into the

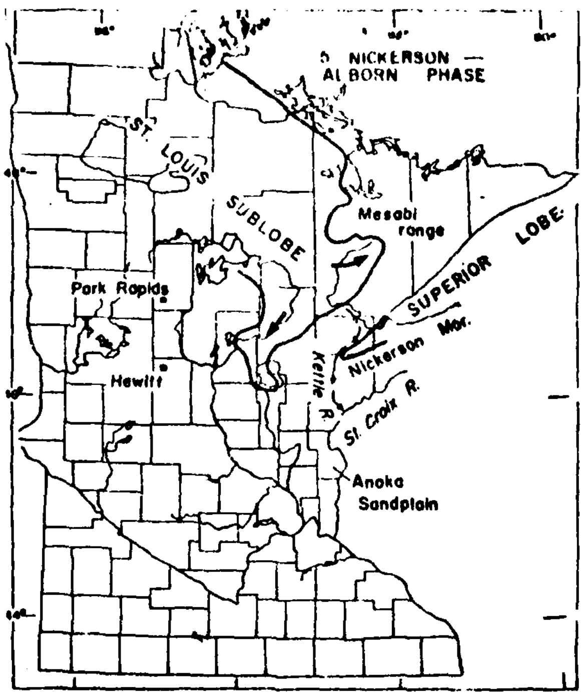
tributaries of the Mississippi River. Aggradation occurred in tributaries including the Cannon, Zumbro, Whitewater, and Root Rivers. Later degradation encised the outwash producing many terraces along the tributaries.

During the Nickerson-Alborn Phase, the St. Louis Sublobe branched from the Des Moines Lobe and advanced eastward (Fig. 15). It buried the Vermilion Moraine and overrode the lake sediment of glacial Lakes Aitkin I and Upham I. The sublobe reached its terminus near Alborn in western St. Louis County. Melt water from the sublobe was diverted southward into the Kettle River, a tributary of the St. Croix River.

The Superior Lobe had withdrawn from its Split Rock-phase position to the Nickerson Moraine. Glacial Lakes Upham II and Aitkin II formed along the ice margin of the retreating St. Louis Sublobe. The lakes supplied increasing amounts of water to the Kettle River. The Superior Lobe withdrew from the Nickerson Moraine and formed glacial Lake Nemadjii (Fig. 15). The lake had an outlet to the Kettle River. Eventually the lake dropped in elevation and formed glacial Lake Duluth which drained directly into the St. Croix River. The vast amount of water draining down the St. Croix River cut down through the older river sediments leaving only scattered terraces high above the rampaging river. The St. Croix eventually cut down into igneous bedrock along much of its course and produced the large potholes at Taylor's Falls, Minnesota.

The Des Moines Lobe retreated during the Agassiz Phase from its terminus in Iowa and followed the axis of the Minnesota River valley.

a



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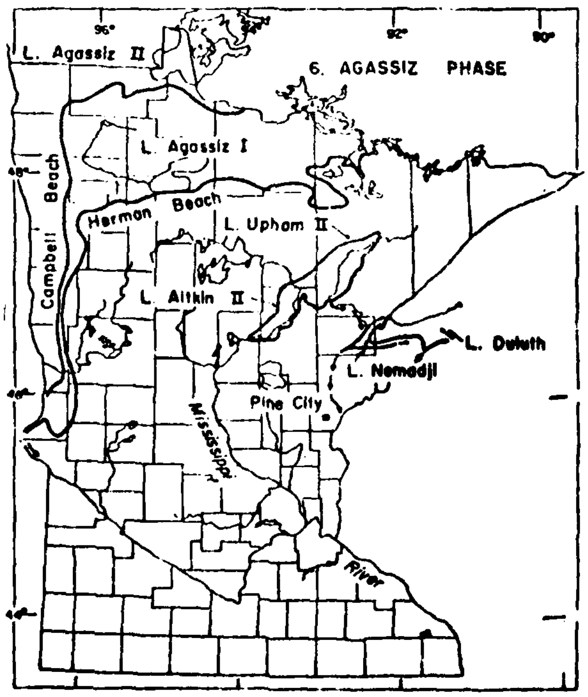


Figure 15. Nickerson-Alborn and Agassiz phases of Wisconsin glaciation in Minnesota (Wright and Ruhe, 1965).

It stopped at the Big Stone Moraine and dispatched great volumes of melt water and outwash down what eventually became the Minnesota River valley. Further retreat of the Des Moines Lobe opened the basin of glacial Lake Agassiz north of the Big Stone Moraine (Fig. 15). The lake expanded and eventually drained southward through the Minnesota River valley. The great volume of water known as the Glacial River Warren cut the outlet gorge as much as 300 feet deep through outwash for hundreds of miles to the Mississippi River at Minneapolis and beyond (Fig. 14). The River Warren carried little sediment compared to its great discharge and thus had great stream power to erode and enlarge the valleys of the Minnesota and Mississippi Rivers. Because of its great discharge and relatively small load, River Warren was able to transport all of the sediment added to it from the Chippewa River and other tributaries in southwestern Wisconsin and southeastern Minnesota, and, in fact, cut its bed to a gradient at least 50 to 100 feet below the modern floodplain. Additional water was added by Glacial River St. Croix, which served as the early outlet for Glacial Lake Duluth. As deglaciation continued the outlets of Lake Agassiz and Lake Duluth shifted to the north and east respectively. The River Warren lost its great discharge and the modern Minnesota-Mississippi and St. Croix rivers came into existence. This occurred about 9,000 years ago (Wright and Ruhe, 1965). Zumberge (1952) concluded that when this occurred, Lake Pepin came into existence in the Mississippi River Valley.

The gradient of the Chippewa River between its mouth and Eau Claire is about 2 feet per mile which is about ten times greater than the present

Mississippi River gradient between St. Paul and La Crosse. Thus the Chippewa has more available stream energy (velocity) to carry a coarser load than the Mississippi. River Warren had a discharge and velocity great enough to completely transport all the Chippewa River sediment. The Mississippi River did not, however, and as a result a delta formed at the Chippewa mouth ponding the Mississippi water forming Lake Pepin. Zumberge (1952) believes that Lake Pepin at one time extended all the way upstream to the Robert Street bridge in St. Paul. Postglacial delta deposition by the Mississippi has filled Lake Pepin from St. Paul to Red Wing, a distance of about 50 miles. Lake Pepin will be continuously reduced in size by the advance of the delta at its head as well as by filling of the lake with silt and clay.

Zumberge (1952) compiled a summary of late-glacial and postglacial events for the segment of Minnesota-Mississippi River system (Fig. 16) as follows:

A. Initial stage—loss of volume in the Mississippi River because the change of outlet of Glacial Lake Azassiz permitted the growth of a delta at the mouth of the Chippewa River (Fig. 16).

B. The continued growth of the Chippewa delta caused early Lake Pepin to extend upstream to the Robert Street bridge in St. Paul. A delta forms at the head of this lake, while silt and clay are deposited in the deeper, quiet waters of early Lake Pepin (Fig. 16).

C. The Chippewa delta grows larger and higher, while the delta at the head of the lake advances downstream to the mouth of the St. Croix, burying the previously deposited silts and clays and blocking the lower end of the St. Croix Valley, thus forming Lake St. Croix (Fig. 16).

D. The continued growth of the Chippewa delta raises the level of Lake Pepin, while the advance of the delta continues to cover previously deposited lake silts and clays (Fig. 16).

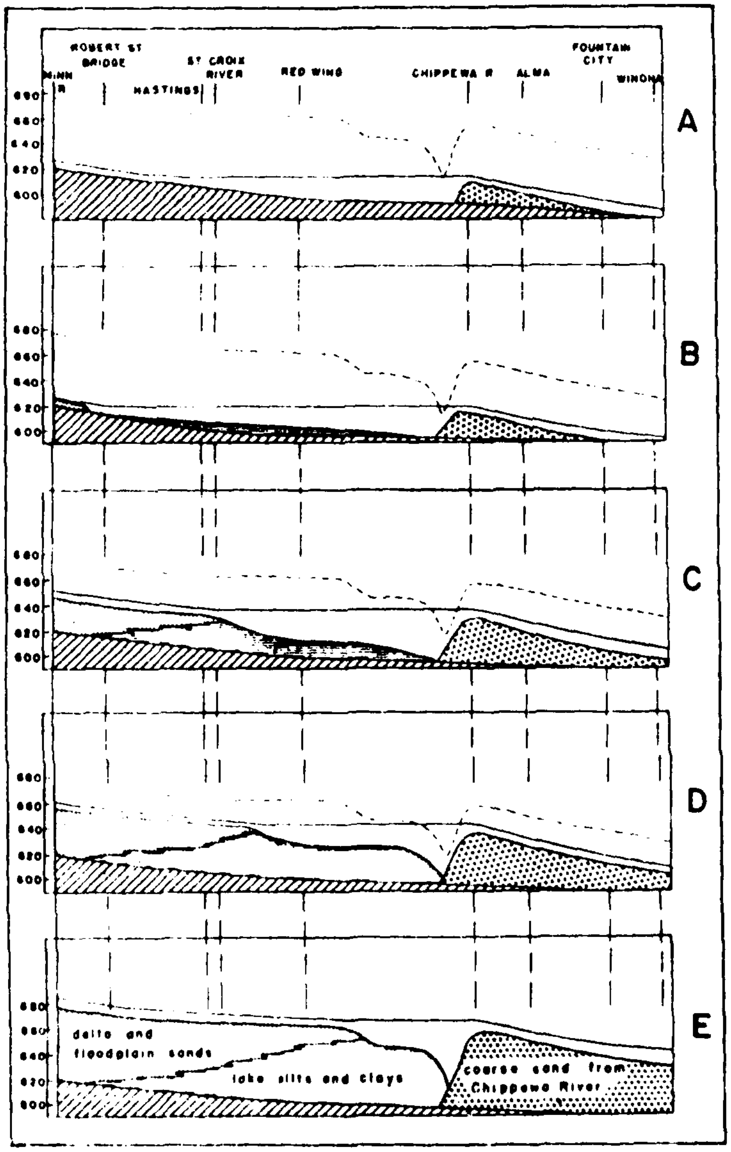


Figure 16.—Diagrammatic history of Lake Pepin (Zumberge, 1952). See text for complete explanation.

E. Present condition of sediments in the valley as shown by Corps of Engineers borings at each lock and dam.

Wisconsin Glaciation in Wisconsin — Wisconsin was probably glaciated many times during the Pleistocene but only drift of Wisconsin age occurs at the surface. Isolated deposits most easily explained by glacial action occur in the classical "Driftless Area" of southwestern Wisconsin, but unforunately no way has yet been found to date them. Some may be pre-Wisconsin.

Wisconsin glaciers covered most if not all of Wisconsin (Fig. 17). Black (1959) believes that Wisconsin glaciers covered the "Driftless Area" but deposited very little sediment. The Wisconsin Stage of glaciation can be subdivided into the Altonian, Woodfordian, and Valderan Substages.

Simultaneous advances of ice, one southeastward from the Des Moines and Superior Lobes and the other westward from the Lake Michigan and Green Bay Lobes, took place about 29,000 to 32,000 years ago, according to radiocarbon dates on spruce logs overrun or incorporated in the drift (Frye and others, 1965). This latest Altonian advance (locally called Rockian) covered much if not all of the state.

The maximum spread of ice during the Wisconsin Glaciation came in The Woodfordian Substage (Fig. 17), when ice from the Lake Michigan and Erie Lobes advanced as far south as central Illinois. Many end moraines were formed during the retreat of the ice margin (Fig. 17). Outwash from [illegible] Mississippi tributaries as much as 100 feet.

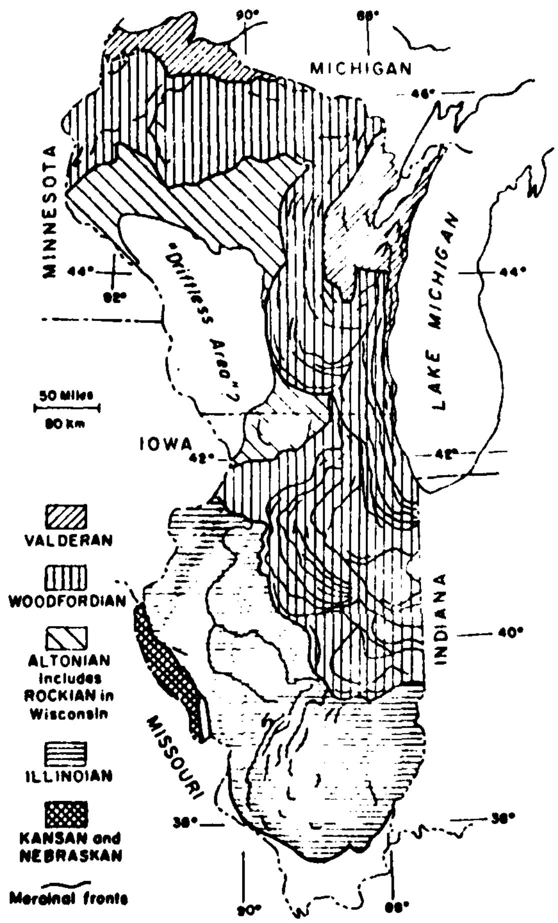


Figure 17. Map of Illinois and Wisconsin showing the distribution of surficial glacial deposits (Frye and others, 1965).

The outwash is largely sand and sandy gravel. In most tributary valleys these deposits form extensive terraces. The Chippewa, Trempealeau, and Black Rivers, have extensive terrace areas composed of sand and sandy gravel. Along the Chippewa River, terraces up to 100 feet high occur adjacent to the present river floodplain (Fig. 18). The terrace surface along the Chippewa River can be followed to the Woodfordian outwash plain northeast of Eau Claire (Fig. 17). The terraces have a gradient of about 4 feet per mile from the mouth of the Chippewa to Eau Claire.

During the Valderan Substage, ice of the Lake Michigan Lobe readvanced to the vicinity of Milwaukee, Wisconsin. The ice buried a forest bed at Two Creeks, Wisconsin that has been radiocarbon dated at 11,850 years B.P. (Frye and others, 1965). It may also have advanced out of the Lake Superior lowland onto the highlands of northern Wisconsin although this has not been definitely established in the field.

The Valders Till of eastern Wisconsin is defined (Frye and others, 1965) as including that till and subsequent glacial and alluvial deposits that accumulated before the dissipation of the continental glacier and the return of sea level to approximately its present position about 5,000 years B.P. Presently available radiocarbon dates suggest that the upper 50 feet of alluvial fill of the Mississippi valey in southwestern Illinois was deposited subsequent to 7,000 years BP (Frye and others, 1965). Thus much of alluvial fill in the Mississippi section within the study area was probably deposited within this same time interval (Fig. 17). The upper 23 feet of fill of the Wisconsin River valley near Portage was

Figure 18.-A Chippewa River terrace about 100 feet high located several miles upstream from Durand. View looking northwest.

deposited rapidly about 6,000 years B.P. (Frye and others, 1965).

Postglacial History — During deglaciation the climate of the Upper Midwest became warmer as evidenced by the northward retreat of the coniferous forest. Streams that formerly carried substantial quantities of glacial melt water became very small by former comparison. Many of the tributary streams began cutting into their flood plains producing terraces marking their former Pleistocene profiles.

Because of the reduction in discharge and velocity during postglacial time, the Mississippi began to aggrade. The Mississippi Valley was thus filled with alluvium until the gradient of the Mississippi was just steep enough to carry the sediment supplied to it by its many tributaries. At this point the Mississippi became a *graded river or a river in equilibrium*.

The Chippewa River carries coarser sediment than the Mississippi above Lake Pepin, thus causing a transporting problem for the Mississippi. To transport the coarse sand and gravel from the Chippewa, the Mississippi had to change the shape of its channel so that the current velocity would increase. The Mississippi normally is considered a meandering river along most its course, but immediately below the Chippewa Delta the Mississippi River was forced to braid. Instead of one main channel, the Mississippi formed many smaller channels that individually had a higher current velocity than a single main channel. Thus, the coarse load of the Chippewa River could be carried by the Mississippi. Many of the small

braided channels can still be seen on topographic maps and aerial photographs throughout the study area.

During postglacial time wind was an important agent modifying the landscape. Many dunes were formed on the sandy terraces along the Mississippi and its tributaries. These dunes are very evident on the terrace between Wabasha and Minnieska (elevation about 700 feet). Loess was also deposited on much of the upland surface during this time.

The change in climate probably produced changes in the character of stream loads throughout the Upper Mississippi River basin. Prairie soils are more easily eroded than forest soils so that the suspended load of the rivers and streams in the basin increased following deglaciation. This is true for all streams in the area except the Chippewa, because the Chippewa primarily drains a forest area.

Physical Characteristics of Mississippi River Sediments - Pool 4

<u>Description</u>

The solid load of a river or stream can be divided into the suspended load and the bed load. Bed-load sediment is composed of grains that roll, slide or bounce intermittently along the bottom of a stream at velocities considerably less than the water itself. Gravel- and sand-size grains (particles greater than .06mm diameter) generally comprise the bed load of most streams including the Mississippi. The suspended load of a river consists of particles small enough to be supported by the water and thus travel at the same velocity as the river or stream. The suspended load normally consists of silt-and clay-size particles (particles less than .06mm diameter) that together are commonly referred to as mud. Some sand-size grains may be carried in suspension during some high-flow periods.

No effort was made during this study to examine the suspended-load sediment in the Mississippi because of the small diameter of the grains involved. Sand- and gravel-size grains are megascopic and are thus easier to work with. Bottom samples were taken from the Mississippi and its tributaries using a Ponar dredge. Additional samples were taken from dredge-spoil piles throughout the main channel area. Each sample was mechanically sieved using Tyler 8-inch screens corresponding to the Wentworth grade scale.

<u>Texture</u>—The texture of a sediment refers primarily to the size and shape of the grains composing the sediment. If the sediment is composed

of grains of uniform size it is said to be well sorted, whereas if it is composed of grains having a wide range of grain diameter it is considered to be poorly sorted. Generally speaking, the greater the distance of bed-load transport, the finer the texture and the better the sorting.

The textures of samples from Pool 4 are shown in Table III. Ten samples were taken from the main channel dowstream from the Chippewa Delta and two samples were taken upstream from the head of Lake Pepin. Lake Pepin was sampled and was found to contain fine mud throughout much of its length and was thus not texturally studied in detail.

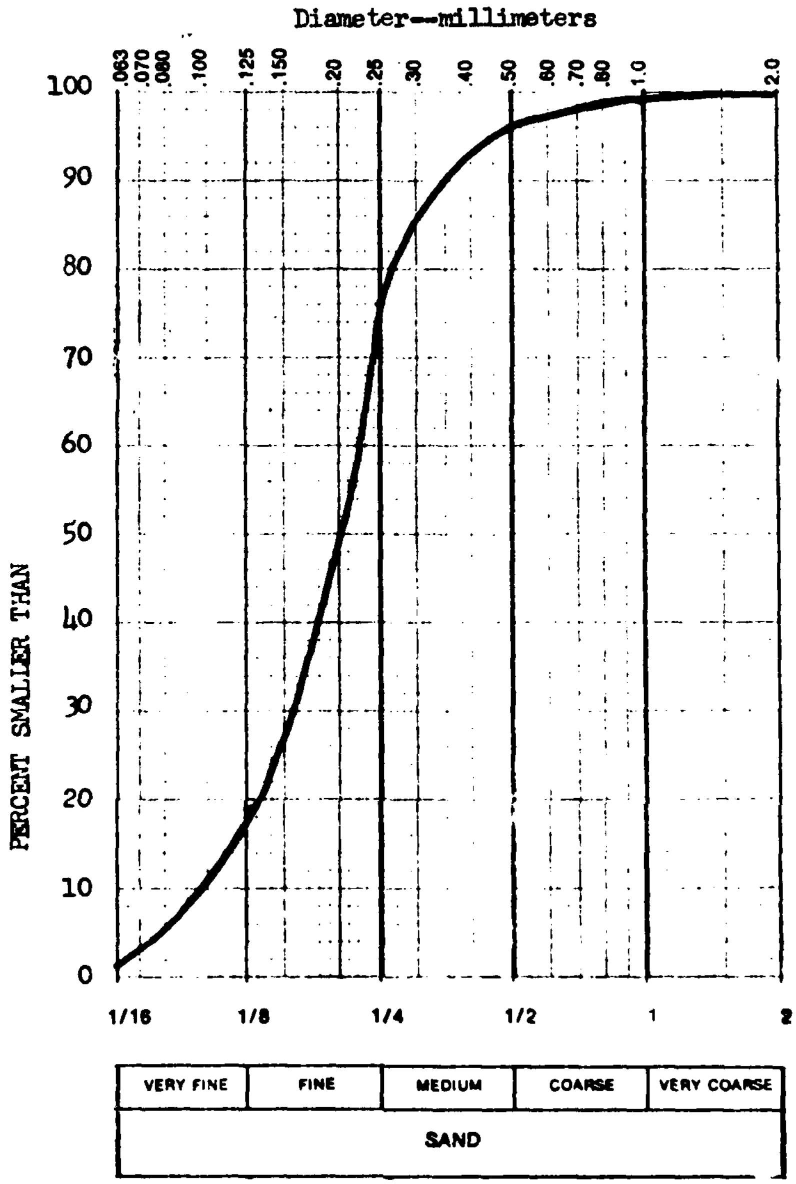
Figure 19 presents a graphic plot of average texture of the two samples taken upstream from Lake Pepin. The curve shown is a cumulative curve that depicts graphically the texture of the sediment. From such a curve, some graphic statistics can be determined such as mean particle diameter and graphic standard deviation in phi (ϕ) units. Phi units are dimensionless numbers used for computational purposes in sedimentology (each Wentworth size class is separated by one phi unit). The graphic standard deviation is a good measure of sorting and is used by Folk (1965) to derive a verbal classification for sorting. The samples would be classified as a well sorted fine-grained sand having a mean particle diameter of .20 mm. The grains appeared to be sub-rounded to rounded in both samples.

The average texture of ten samples taken from the Mississippi main channel downstream from Lake Pepin is shown in Figure 20. The samples were all coarser than those above Lake Pepin and had a mean particle

TABLE III

Textures of Samples from Pools 4, 5, 5A, and 6, Upper Mississippi River

			Sample Location		Percent					
					Mesh 230	120	60	35	18	10
Pool No.	Sample No.	Mileage	Spoil	Channel Bottom	Very fine Sand	Fine Sand	Med Sand	Coarse Sand	Very Crs. Sand	Granule
4	5	763.5		X	.2	2.6	59.5	36.2	1.6	.2
	6	759.2	X		.1	3.0	49.2	43.7	6.3	.9
	7	763.0	X		.2	4.4	52.3	34.4	7.2	1.5
	13	763.0		X	.1	1.2	32.0	44.3	16.2	6.3
	14a	761.9		X	.2	5.6	36.0	48.8	8.4	1.2
	15	760.1		X	0.0	.9	15.9	40.4	30.6	4.6
	16	757.6		X	.4	9.2	64.0	21.8	2.9	1.2
	17	755.1		X	.5	6.0	66.9	23.1	3.6	.5
	18	754.0		X	.6	4.2	31.5	44.0	16.1	4.0
	19	753.0		X	2.1	11.1	70.5	14.9	1.5	.1
5	3	749.3	X		.2	2.6	35.9	46.8	11.2	3.0
	5	741.8		X	.1	2.9	35.3	43.4	13.2	5.2
	7	745.1		X	.5	4.7	68.5	13.2	13.1	.1
	9	743.7	X		2.3	9.2	38.8	23.6	14.8	11.7
5A	1	735.7		X	.2	2.0	29.6	49.0	18.3	1.1
	2	733.7		X	.2	7.8	39.3	37.0	13.9	2.0
	3	731.3		X	.1	.1	33.6	43.7	18.6	3.9
	4	729.5		X	5.1	26.7	34.9	16.1	7.6	9.6
	5	730.7	X		.5	3.9	43.2	39.4	11.0	2.2
6	1	715.6		X	.5	3.4	40.1	39.0	13.0	3.4
	2	718.8		X	2.0	12.6	68.3	16.2	.8	.1
	3	720.2	X		1.3	10.3	66.4	18.5	12.1	2.7
	4	721.9	X		.5	2.7	57.4	35.0	5.4	1.8
	5	724.7		X	.8	2.3	41.5	50.0	6.1	1.6
	6	726.6		X	.3	1.5	26.0	67.4	4.8	.1



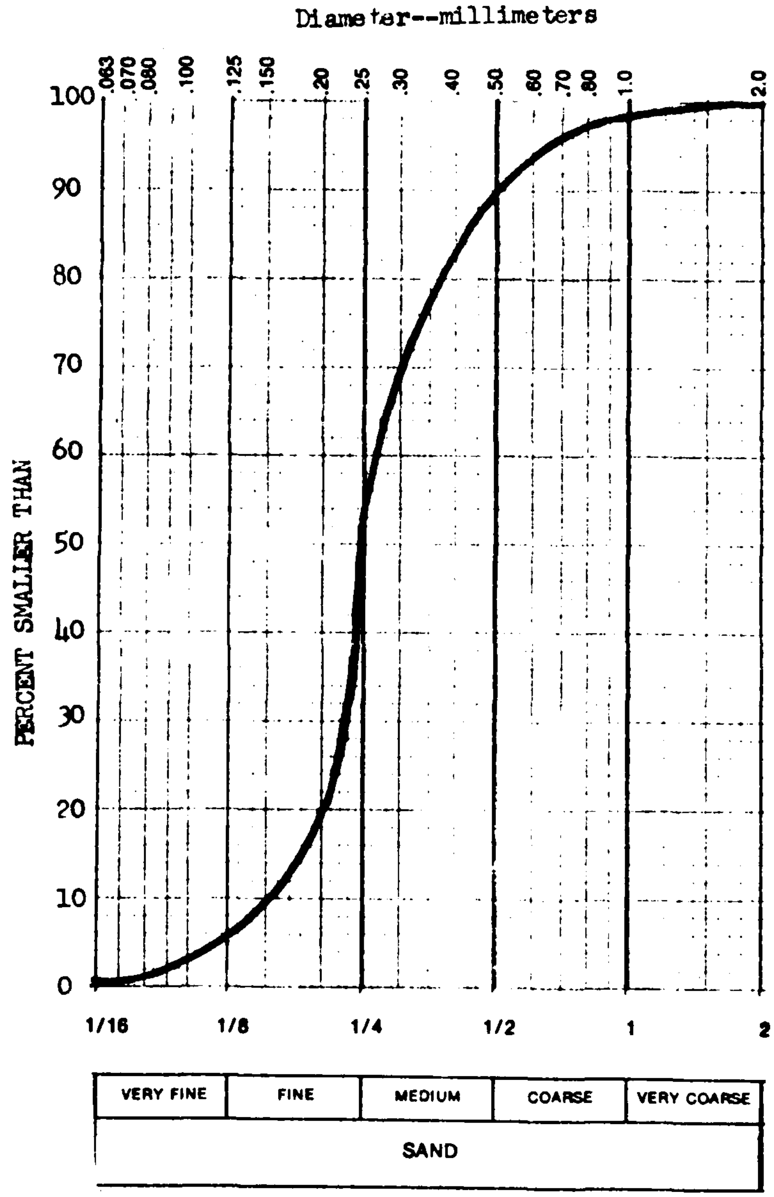
Graphic Statistics

Mean particle diameter-- .20 mm

Standard deviation-- .50∅

Well sorted

Figure 19. Cumulative curve of upper Pool-4 bed-load texture.



Graphic Statistics

Mean particle diameter-- .27 mm

Standard deviation-- .69ø

Moderately-well sorted

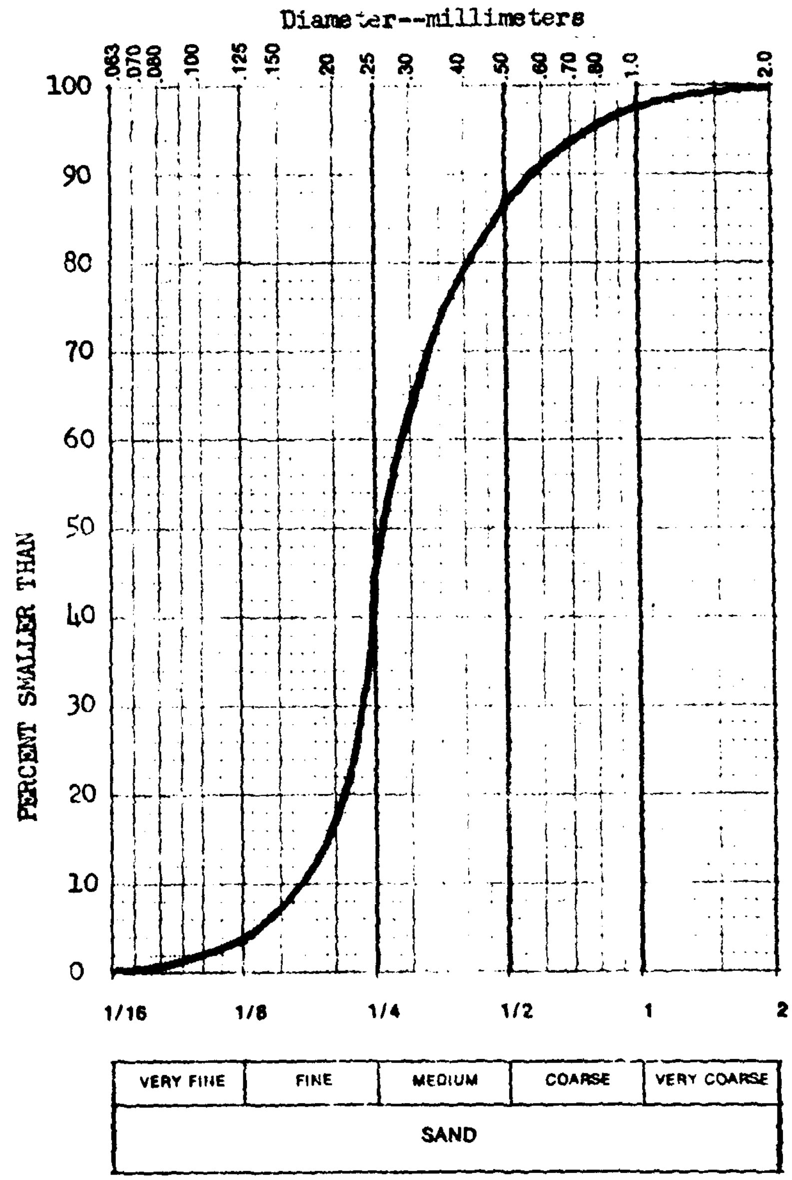
Figure 20. Cumulative curve of Pool-4 bed-load texture.

diameter of .27 mm. The samples had a larger standard deviation and were thus not as well sorted as the samples above Lake Pepin. The samples would be classified as a moderately-well sorted medium-grained sand. The grains appeared to be more angular than those samples from above Lake Pepin.

The small size of the tributary streams entering the Mississippi in Pool 4 above Lake Pepin necessitates deleting them from study. The Chippewa River below Lake Pepin has a large discharge and stream load making it a very important tributary of the Upper Mississippi River. Samples of bed-load sediment from the Chippewa were subjected to size analyses the same as those from the main channel of the Mississippi. The results of the analyses are shown in Table IV. The average texture of the samples is graphed in Figure 21 as a cumulative curve. The Chippewa River sediment is slightly coarser than the Mississippi sediment below the mouth of the Chippewa. It has a mean particle diameter of .32 mm and is slightly more poorly sorted than the Mississippi River sediment.

Source—The bed-load sediment in Pool 4 above Lake Pepin is derived from sediment sources in the tributary basins of the Mississippi. This would primarily include the river basins of the Minnesota, St. Croix, and Upper Mississippi above St. Paul. The bed-load sediment contains rock particles found in each tributary basin including shale fragments. Shale can only be derived from sources in southwestern Minnesota which

CHIPPEWA RIVER



Graphic Statistics

Mean particle diameter-- .32 mm

Standard deviation-- .71Ø

Moderately-well sorted

Figure 21. Cumulative curve of Chippewa bed-load texture.

TABLE IV

Textures of Samples from Tributary Streams Entering Pools 4, 5, 5A, and 6

Tributary	Sample No.	Miles Upstream	Sample Location: Bar	Sample Location: Channel Bottom	Percent: Mesh 230 Very Fine Sand	120 Fine Sand	60 Med. Sand	35 Coarse Sand	18 Very Crs. Sand	10 Granule
Chippewa	4-3	.5		x	.2	3.9	43.8	44.6	10.3	1.3
	4-4	1.2		x	.1	.4	36.4	49.6	8.8	4.7
	4-11	.2		x	.1	5.6	41.3	34.8	13.2	5.2
Zumbro	5-2	.5		x	4.0	30.5	55.9	8.8	1.0	0.0
	5-10	5.0	x		2.0	25.0	61.0	7.2	6.1	0.0
Trempealeau	6-7	.3		x	1.4	1.9	29.6	61.2	5.6	.2

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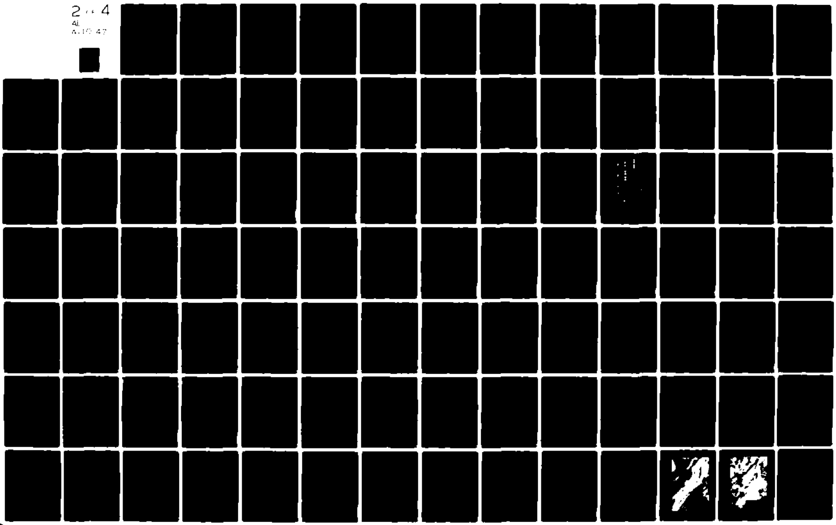

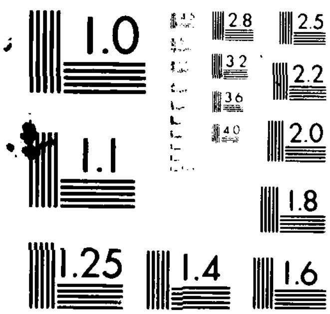

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

are drained by the Minnesota River.

Lake Pepin has no measureable current and is thus, for all practical purposes, a true lake. The Mississippi River deposits its bed load at the head of Lake Pepin and forms a delta into the lake. Thus, all bed-load sediment is trapped in Lake Pepin. A substantial part of the suspended load is also deposited in Lake Pepin because of the absence of any appreciable current in the lake. Virtually all bed-load sediment downstream from Lake Pepin must then be derived from tributaries below the lake.

The Chippewa River is the main source of bed-load sediment in Pool 4 below Lake Pepin. The bed-load samples from the Chippewa River and the main channel of the Mississippi have very similar textures (Fig. 20 and 21). The slight decrease in average grain size and standard deviation can be attributed to normal grain abrasion during transport. The samples from both rivers are petrologically the same. That is, the sand grains from both rivers are composed of the same type of rock fragments. The coarse-sand fractions of samples from each river were examined using a binocular microscope. The grains were separated into five categories of rock types including: igneous and metamorphic grains; quartz grains; carbonate and sandstone grains; shale grains; and miscellaneous grains. The results are tabulated in Table V. The location of each sample is the same as in Table III and IV.

The samples from Pool 4 have up to 41 percent igneous and metamorphic grains with the remainder being primarily quartz grains. The igneous and

metamorphic grains include rock types characteristic of the Superior Upland Province. The relative proportion of quartz grains compared to igneous and metamorphic grains is low compared to most rivers and streams. Evidently the grains have not been exposed to extensive chemical weathering and long transport by water. No shale, sandstone, or carbonate grains were identified in any samples examined from Pool 4. The samples did contain, however, some Lake Superior agate which is characteristic of the Superior Upland Province. Numerous grains were found with an iron oxide coating on the outside of the grain. These grains appear as shiny, metallic gray particles and can be easily recognized in the many spoil piles throughout the pool. The iron coatings occur on all kinds of grains except quartz grains. The iron oxide is probably hematite or goethite and was formed by precipitation from groundwater in an alternating reducing-oxidizing environment. Such an environment could be found where the water table fluctuates in a post-despositional environment. The iron-coated grains occur in amounts up to 6 percent in Pool 4 bod-load sediment.

The Chippewa River acquires most of its bed-load sediment from (1) glacial terraces, and (2) easily eroded sandstones. The terraces are contributing the most sediment to the river based on field and petrologic studies of the sediment. Dams on the Chippewa at Eau Claire and Chippewa Falls prevent significant quantities of bed-load sediment from reaching the river below Eau Claire. Thus, most of the bed-load sediment reaching Pool 4 must come from that stretch of the Chippewa River from Eau Claire to the junction with the Mississippi. All along that stretch of the

Chippewa are many terraces composed of sand and gravel. The terraces are up to 100 feet high and are subject to undercutting by the Chippewa. Figure 26 shows the Chippewa River in contact with the face of a glacial terrace a short distance upstream from Durand. The terrace face is very steep and is continually being eroded by the river. A sample taken from the terrace shown in Figure contained slightly more than 3 percent iron-coated pebbles. The relative proportions of igneous and metamorphic grains compared to quartz grains is similiar to samples taken from the Chippewa and Mississippi Rivers (sample C-1, Table V).

Table V

PETROLOGIC COMPARISON OF SAND SAMPLES FROM POOLS 4, 5, 5A and 6

Sample No.	Percent				
	Ign. & Met.	Quartz	Carbonates	Shale	Misc.
5-2	17.6	75.3	2.3	0.0	4.7
4-4	30.9	63.4	0.0	0.0	5.8
4-14	40.8	55.2	0.0	0.0	4.0
5-5	35.8	59.5	1.2	0.0	3.7
6-2	35.0	61.9	3.0	0.0	3.0
C-1*	47.8	48.1	1.0	0.0	3.2

*Chippewa River terrace

Erosion Rates—The computation of sediment yield from streams has been done for years by the U.S. Geological Survey. Generally, suspended sediment samples are taken to determine the sediment discharge of a stream. Long-term suspended sediment records usually produce reliable estimates of sediments yields for most streams. From the

sediment concentration and the water discharge, the daily sediment load in tons is computed. From these data, monthly and yearly sediment yields are determined.

No satisfactory method exists for routinely measuring the bed load of a stream. Many analytical and empirical bed-load formulae have been developed but none has yet proved entirely satisfactory under natural conditions. Mack (1970) indicates that the bed Load in streams of the Upper Mississippi River Basin ranges from 0 to 40 percent of the total stream load. He used an average of 10 percent for most streams in the basin. Hindall and Flint (1970) calculated that the total suspended load carried by the Chippewa River is about 162,180 tons each year based on a 23-year average. Using Mack's average bed-load values, the Chippewa supplies no more than 64,872 tons of bed load each year (about 43,000 cubic yards). This value appears to be much too small for the Chippewa when one looks at dredging records of the Mississippi below the mouth of the Chippewa. In 1965, the Corps of Engineers dredged 300,000 cubic yards of bed load from the Chippewa River a short distance upstream from its mouth. They returned one year later and found the hole completely filled with sediment. Thus, the minimum amount of bed-load sediment carried by the Chippewa River to the Mississippi is 300,000 cubic yards each year. In actuality, the amount is probably much greater because it is not known how long it took the Chippewa River to fill the hole dredged by the Corps.

The channel from the Chippewa River downstream from Eau Claire, is relatively straight and is braided in some stretches. This demonstrates that the Chippewa is carrying a very high bed load.

The relation between transport rate of sands, mean velocity, and depth represent an empirically useful relationship, one that Colby (1961) used to estimate bed-load discharge for the Rio Grande River. Using his technique, the Chippewa may be transporting as much as 3,500,000 tons of sand and gravel each year based on a median diameter of .30 mm, average water depth of 3 feet, mean velocity of 3 f.p.s., and a channel width of 500 feet. This figure seems more in agreement with the channel morphology and dredge records from the Chippewa and Mississippi River.

Some engineers might dispute the importance of the Chippewa River as a major source of sand and gravel in Pool 4 because one year after dredging the Chippewa in 1965 there was no noticeable quantitiative change in dredging in the Pools dowstream from the Chippewa. This can best be explained by noting that the amount dredged from the Chippewa may have been a small percentage of the total bed-load discharge that year. There is also the problem of sand and gravel relocation within each pool. Stream and wind erosion of the many spoil piles along the main channel of the Mississippi result in re-dredging the same sand over and over again making dredging records somewhat misleading. Many individuals also fail to recognize that the Chippewa River has an abnormally steep gradient (2 ft/mile) and relatively high-current velocity (about 3.0 f.p.s.) average) which provide the river with great competency and capacity.

Climate

The climate of the study area is typically continental because of the lack of proximity to oceans or other large water areas. Because the flood plain is only about 550 feet above sea level, however, and because it is flanked by bluffs which rise as high as 650 feet above the valley floor, the climate of the valley is moderated. Winters are less severe in the study area, for example, than they are in the Rochester, Minnesota, area which is only about 45 miles to the west.

The annual average temperature has ranged from 41.9°F in 1917 to 51.6°F in 1931. The mean annual average temperature is 46.4°F (LaCrosse, Wisconsin, data). The average temperature ranges from a minimum of 6.9°F in January to a maximum of 83.1°F in July (Upper Mississippi River Comprehensive Basin Study Committee, 1970). The maximum summer temperature at Winona over a 36-year period was 108°F while the minimum temperature during the same period was -40°F (United States Department of Agriculture, 1941).

The date of the average last killing frost over a 16-year period at Winona was May 3, while the date of the first average killing frost over the same period was on October 8. The length of the growing season at

Winona averages 158 days.

Most precipitation (LaCrosse, Wisconsin, data) occurs in June and the least precipitation occurs in December, January, and February. The minimum annual precipitation of 16.8 inches occurred in 1910 and the maximum annual precipitation of 42.4 inches occurred in 1938. The mean annual precipitation is 30.9 inches.

During January, winds blow most frequently from the northwest with an average speed of 11 mph. Winds blow most frequently from the northwest in April, also, with an average speed of 14 mph. Southerly winds with an average speed of 8 mph prevail during July. October winds are generally southerly at a speed of about 10 mph.

SOILS

The soils of the floodplain are alluvial and they vary in texture from silty clay to sand. The composition of the soil depends upon the manner in which the soil was laid down. The strata are composed of clay, silt, sand and gravel and are very irregular. Stream banks plainly show the varying thickness of the different materials and in many places the lack of continuity of the sand and gravel layers above low water level.

Sand and gravel strips border most sloughs, but some of the larger, more elevated areas between the sloughs are covered with heavy silty loam which is underlain with sand or gravel. Prior to impoundment, these silty tracts were usually managed for hay (Marsden and Shafer, 1924).

Subsequent to the implementation of the 9-foot channel project, many of the original soil profiles have been overlain with silt and sand.

Ground Water

The most important aquifers in the Upper Mississippi River Basin are sand, gravel, limestone, dolomite and sandstone. Massive deposits of clean gravel were deposited by swift glacial streams during the Pleistocene Epoch. Such deposits are commonly found in valleys now occupied by streams that provide rapid recharge during times of high streamflow.

The dolomite strata of the area are generally cavernous and they give rise to large springs. The sandstone strata which underlie the Oneota dolomite serve as excellent aquifers.

The valley of the Mississippi River is filled with as much as 200 feet of various sediments, some of which are preserved as terraces. Within the alluvium are sand and gravel aquifers which yield more than 1,000 gallons per minute to single wells.

Recharge to most aquifers is very rapid. Wells placed close to the river will, in most cases, induce water from the river to flow toward the wells. The alluvium along most reaches of the study area yields adequate water for most industrial and municipal uses.

Representative water samples from unconsolidated aquifers at Winona

contain an average of 0.99 ppm iron, 44 ppm sulfate, 9.5 ppm chloride, and 280 ppm hardness expressed as calcium carbonate (Upper Mississippi River Comprehensive Basin Study Committee, 1970).

In 1972, Winona well water was tested by the Bureau of Sport Fisheries and Wildlife Fish Control Laboratory at LaCross, Wisconsin. The parameters of the water from this shallow, sand point well were as follows: resistivity - 1277 ohms, pH - 7.42, total alkalinity as C_aCO_3 - 331 ppm, total hardness as C_aCO_3 - 384 ppm, calcium hardness as C_aCO_3 - 260 ppm, ammonia nitrogen - 0.38 ppm, nitrite - less than 0.005 ppm, nitrate - 0.05 ppm, sulfate - 42.5 ppm, ortho phosphorous as PO_4 - less than 0.05 ppm, total iron - 0.28 ppm, manganese - less than 0.05 ppm, sodium - 32.5 ppm, calcium - 59.0 ppm, magnesium - 18.3 ppm, potassium - 3.7 ppm.

Hydrology

The study area receives an average of 32 inches of precipitation per year and the average annual potential evapotranspiration in 24 inches (Minnesota State Planning, 1970).

About one-fourth of the average annual precipitation in the basin surrounding the study area appears in tributary streams as runoff. Tributaries of the Mississippi River in the study area have much steeper gradients than the Mississippi itself, thus the flow of the tributaries is more variable. Minimum flows of the Mississippi and its tributaries generally occur in August and September and in January and February (Upper Mississippi River Comprehensive Basin Study Committee, 1970).

The drainage area of the basin above Winona includes 59,200 square miles. During 39 years of record, the average discharge at Winona was 24,810 cfs, while the minimum flow was 24,810 cfs, on December 29, 1933 and the maximum flow was 268,000 cfs on April 19, 1965.

Floods of great magnitude have been known to occur throughout the study area for many years. Bunnel (1897) documents severe floods in 1728, 1785, 1826, 1832, and 1844. During the flood of 1844, almost the entire site of Winona was reported to have been covered with water.

Floods appear to have increased in frequency and intensity in recent years, however. During the past 93 years, five floods at Winona have surpassed a discharge of 175,000 cfs. One of these floods occurred in 1880 (180,000 cfs), and the other four have taken place in the past 22 years (1951, 1952, 1965 and 1969). The 1965 flood exceeded the 1880 flood by 88,000 cfs. The 1965 flood caused an estimated $225,000,000 damage to public and private property along the mainstem of the river. A summary of flood data is presented in Table VI (Minnesota State Planning Agency, 1970).

Table VI Flood Data, Mississippi River at Winona

Date of Flood Crest	Stage (ft.)	Discharge (cfs.)
June 18, 1880	17.00	180,000
April 9, 1897	16.50	163,000
April 27, 1916	16.20	155,000
March 30 to April 1, 1920	15.90	149,000

Table VI Flood Data, Mississippi River at Winona (Cont.)

Date of Flood Crest	Stage (ft.)	Discharge (cfs.)
April 15-16, 1922	15.20	137,000
April 18, 1951	17.40	178,000
April 20, 1952	17.90	190,000
May 7, 1954	16.25	156,000
April 19, 1965	20.77	268,000
April 19, 1969	19.44	218,000

The mainstem of the Mississippi River has a large drainage area and a broad, flat flood plain with a considerable flood storage capacity. Floods have occurred in the study area during all seasons, but those of greatest magnitude have occurred during the spring. Approximately 75% of all floods at Winona have occurred in April, May and June. Severe spring floods are caused by a combination of meteorological conditions including deep frost penetration; an extensive moisture-laden snow cover in the Minnesota, Mississippi, St. Croix and Chippewa River drainage areas; and an extremely late spring with a sudden thaw in April accompanied by rain.

The entire life of the 9-foot channel project has taken place during the longest recorded fluvial period in recent history. One can only speculate as to the consequences of a prolonged drought such as the one which occurred in the 1930's. The flow characteristics of the Mississippi River at extremely low flow are shown in Figure 2/6.

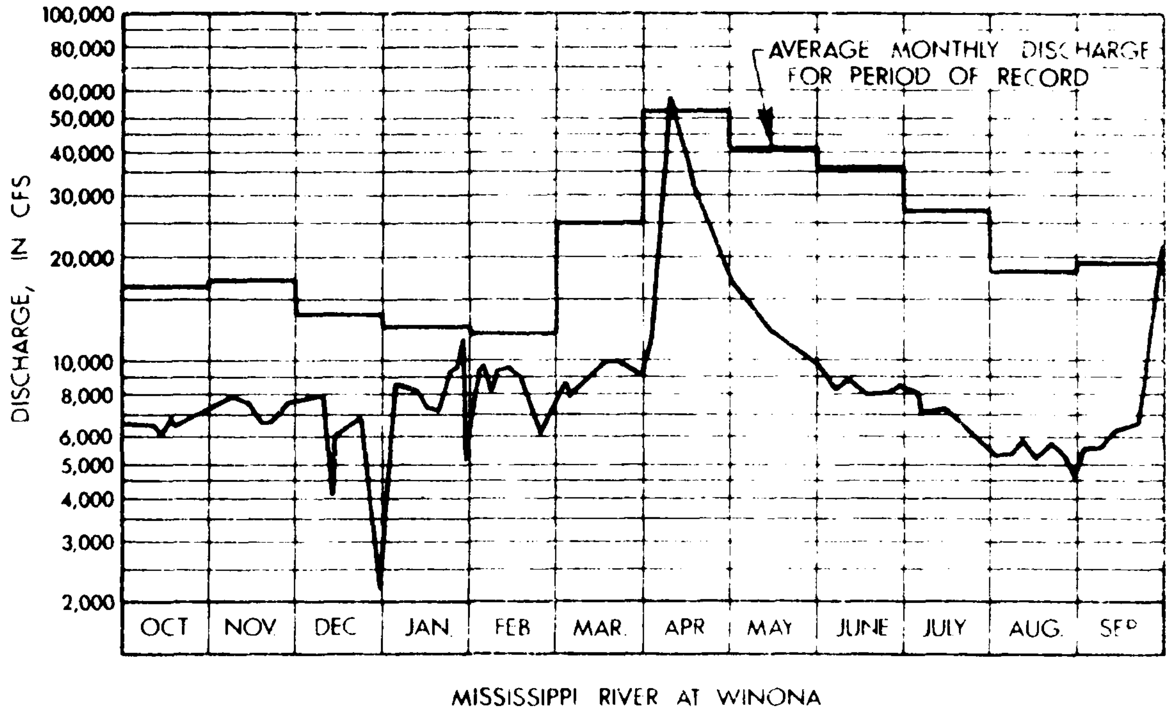

Figure 7/6. The Mississippi River at Winona, Minnesota During the Record Low Flow Year of 1933–1934 (Minnesota State Planning Agency, 1970).

LAND USE

Man's land use patterns in the watershed of the study area have greatly accelerated the relentless erosion of the land. Contour farming and strip cropping were not begun in the area until the late 1930's. As a consequence, early farming practices were extremely destructive to the land. Farming was done, in the early days, with little care given to the precipitous hillsides. Conservation, to the early farmers, meant getting the most use out of every piece of land that they owned. Consequently, they plowed land that should not have been plowed. Hillsides that were too steep to be plowed were burned, grazed, and logged. Floods in tributary valleys were extremely common at all seasons of the year and alluvium from the uplands caused the aggradation of most valley floors. This aggradation can be easily proved by examining buried soil profiles exhibited in the cut banks of valley streams. Entire valley communities were slowly inundated, in some instrances, by sand and silt from the uplands (Winona County Historical Society, 1962). Much of the alluvium from the tributary valleys ultimately was washed into the mainstream of the Mississippi River. Even today, the watershed is severely abused by agricultural practices. Steep slopes, in most areas, are still plowed and grazed. The fragile sand terraces of the Chippewa River, for example, are still grazed to the water's edge.

All of the tributaries of the study area have much steeper gradients than the Mississippi River, and the tributaries are still choked with sand and silt which accumulated in the tributary valleys during the era of maximum soil erosion from 1880 until 1950. The tributaries of the

Mississippi River presently carry more sand and silt to the Mississippi than the river can carry away. Virtually every tributary valley of the Mississippi has a delta at its mouth - mute evidence of the sediment lost to the river. The wing dams and closing dams of the 4½-foot and the 6-foot channelization projects have apparently trapped much of the sediment brought in by the tributary streams.

AIR QUALITY

The air quality in the study area is generally good. Thermal inversions occur frequently during Indian summer weather in September and October. The inversions are usually of short duration, however, and the area is not heavily populated or industrialized. Hence, few air pollution problems exist.

The coal burning power plant owned by the Dairyland Power Cooperative at Alma, Wisconsin, has caused severe local problems and the plant's plume is sometimes evident as far downstream as Winona. A new, taller stack is being constructed, however, and new cleansing devices are being installed to alleviate the situation.

The City of Winona, in recent years, has surpassed the Minnesota Pollution Control Agency standard of 15 ton/sq.mi./mo. for average dustfall. The average figure in the city for 1968 was 13.9 T/sq. mi/mo.; for 1969 it was 29.95 T/sq. mi./mo; and for 1970 it was 34.08 T/sq. mi./mo. Airborne particulate matter exceeded the MPCA standard of 75 micrograms/cubic meter on four occasions during a three-month study by Schwer and Russel (1972). The authors concluded that the particulate matter in the air of the city was generated within the city.

Biological Aspects

Terrestrial Vegetation

Except for those forests which were clear-cut prior to filling the pools, terrestrial vegetation has not changed significantly since inundation by the waters of the 9-foot navigation project. The upper third of each pool has retained the general characteristics of the land prior to the dams, thus retaining vegetative cover with little change. Some loss was inevitable with high-water tables, but those species native to the flood plain are usually able to withstand prolonged periods of high water.

The river bottom is comprised of the following commercially valuable tree species: silver maple (*Acer saccharinum*), American elm (*Ulmus americana*), slippery elm (*Ulmus rubrea*), green ash (*Fraxinus pennsylvannica*), white ash (*Fraxinus americana*), Eastern cottonwood (*Populus deltoides*), black willow (*Salix nigra*), river birch (*Betula nigra*), and swamp white oak (*Quercus bicolor*). Tree species of minor importance present in the flood plain are basswood, hickory, box elder, and black walnut.

The understory of a heavily stocked stand of the forest type is generally sparsely vegetated with shrubs and grapes, whose vines twine up into the forest canopy. In more open stands, heavy stands of shrubs including prickly ash, red and green dogwoods, poison ivy, button bush, and thick patches of silver maple and cottonwood reproduction are common.

Leafy vegetation on the flood plain meadows include grasses such as gramma, big and little bluestem and bluegrass. On the marsh borders, dikes and damper meadows, cord grass, reed canary grass, rice cut grass, several

species of sedges, wild millet, smartweed, <u>Ergrostis</u> and <u>Paspalum</u> can be found in numbers.

<u>Aquatic Vegetation</u>

The following is excerpted from a paper written by Green (1960) on ecological changes of the Upper Mississippi River since inception of the 9-foot channel. While Green's report covers the river for the entire length of the refuge, the statements are definitely applicable to Pools 4, 5, 5A, and 6. There are no unusual variations in any of these pools to warrant separate discussion, thus Dr. Green's records are quoted below:

"The Upper Mississippi River valley is unique in its flora and fauna. It enjoys conditions not generally associated with its geographic location. What has been referred to as a "pseudo-Carolianian zone" extends north along the Mississippi into the Alleghanian Zone. Thus, refuge flora and fauna, although primarily Alleghanian, have representatives of Carolinian species as well as occasional Canadian forms. A feature making the refuge even more interesting is the overlapping of eastern and western species and subspecies. There are also several high "sand prairie" areas scattered along the length of the refuge, offering habitat conditions normally found much farther west. These sand areas reach elevations high enough to protect them from severe floods, and consequently have developed a flora very distinct from that of the true flood plain, with plants of dry upland prairie predominating.

At the time the refuge was established, the river bottoms were primarily wooded islands, with deep sloughs the rule, but with hundreds of

lakes and ponds scattered through the wooded areas. There were some hay meadows on the islands, together with some small farming areas, but the bottoms were essentially wooded. Marsh development was limited to the shores of the lakes and guts leading off the sloughs. Marsh flora was also limited, with river bulrush making up the dominant habitat. These marshes often dried up completely by the end of the summer. Also, many lakes and ponds dried up completely, while water levels in others receded markedly. Fish rescue work was a big activity, with crews rescuing fish trapped in bottomland lakes and ponds when the river receded.

Early investigators such as Vernon Bailey, F. M. Uhler, and A. O. Stevens found there was a nucleus of marsh and aquatic species present in the bottoms, but not in great abundance. Further, because most of the lakes and marshes were subject to periodic flooding and dried out in the summer and fall, marsh and aquatic development was limited. Bailey suggested whatever means possible to insure water in the lakes and marshes, and advocated construction of retaining dams to hold back flood waters.

Uhler also considered frequent changes in water levels of the flowing channels and the periodical or seasonal fluctuations in the lakes and ponds to have a greater effect on the development of aquatic plants in general than any other factor. He, too, suggested construction of small dams to hold water in lakes and ponds when the water receded in the summer.

Constant drying out of marsh areas and ponds resulted in considerable loss to marsh and aquatic species, especially the annual plants. Re-seeding occurred during periods of floods in the spring and fall, but good aquatic

beds were limited, and before they became well established recurring drying out would again eliminate or greatly reduce such growth.

In the early thirties the Corps of Engineers initiated work on the 9-foot channel project for the Upper Mississippi. Thirteen of the 26 locks and dams constructed in connection with this project are located on the Upper Mississippi Refuge, and the first pool within the limits of the refuge was filled on May 29, 1935. The last pool on the refuge was filled in 1939.

The impoundment abruptly changed the river bottoms from an area of wide fluctuations in pool levels ranging from floods in the spring to drying out in the summer, to an area of semi-stabilized water in which, while spring floods still occur, the bottoms do not dry out in the summer. Thus, instead of wooded islands and dry marshes, we now have excellent marsh and aquatic habitat, with fairly stable water levels throughout the year. Even the two record floods in the spring of 1951 and again in 1952 do not alter the fact that water conditions are much more stable now than they were prior to impoundment. Spring floods always occurred, and they can be expected annually. However, instead of drying up in the summer and winter, there is now water available throughout the year in the marshes, lakes, and ponds. Lack of marsh and aquatic plants is no longer a problem, and fish rescue is a thing of the past. Hay meadows and timbered areas are now in marsh, which offers excellent habitat for furbearers and waterfowl.

In each of the thirteen pools on the refuge three distinct zones occur. The upper end of each pool is in essentially normal river condition, where the water levels were not raised to any extent. In this portion of the pools

marsh development is limited, and the old condition of deep sloughs and wooded islands is found. In the middle of each pool, impoundment backed up water over islands and old hay meadows, spreading out over large areas of comparatively shallow water. It is in the middle portion of the pools that the best marsh development occurred. Immediately above each dam the water was impounded to a depth which precluded marsh development, and at present this area is essentially deep, open water, in which some aquatic growth occurs but in which there is practically no marsh.

The best marsh development on the refuge occurs north of the Wisconsin River. In this area, especially in Pools 4-7, the pools are short and impoundment had more pronounced effect on the development of habitat. Pools 8 and 9, although long pools, have developed much more than the long pools south of the Wisconsin River.

The year following impoundment, very dense beds of Muhlenberg's smartweed came in, often in such dense beds that the bottoms took on the reddish tinge of the blooms. For several years this species supplied an abundance of duck food. It was the growth of this species which led to the enthusiasm with which Service personnel greeted initial improvement following first impoundment. For about five years following flooding this species produced an abundance of seed and during that time held the distinction of being the most important single species of duck food on the entire refuge. After about five years it was found that although in some areas it continued to make vegetative growth, in the few areas where it still hangs on it is almost entirely sterile. With the disappearance of this plant many areas

had greatly reduced aquatic growth, but since then various other aquatics, notably the pondweeds, have come in and have replaced it satisfactorily.

River bulrush, which was the most common marsh species prior to impoundment, has continued to be an important marsh plant. Coming in dense, solid stands for several years following impoundment, this species deliquesced for a few years, but has since made a comeback and is at present an important marsh species, especially for muskrats. Although this species seldom sets seed to any extent on the river, there have been years when it seeded heavily, and then it was of considerable value to waterfowl also.

Round-stemmed bulrushes do occur, however, and are spreading more each year. Of these, hard-stemmed bulrush occurs rarely, although near Thomson, Illinois, an extensive marsh away from the river formerly occurred. This marsh has since been drained. Slender bulrush was formerly more common than soft-stemmed bulrush, but the latter has increased to the point now where it is even more common than the slender species. When impoundment first occurred round-stemmed bulrushes could be found in only small scattered patches interspersed with other marsh plants, but at present good-sized beds in solid stand can be found.

Cattail is still rare, although extending its range somewhat. Most of the stands are _Typha latifolia_, although there are two small areas in which _T. angustifolia_ occurs.

Phragmites is important cover in Pools 5 and 8, although it is rarely found elsewhere on the refuge except in these stands.

Extensive marginal beds of smartweed and millet occur on most ridges for the entire length of the refuge. Seven species of smartweed occur, although Pennsylvania smartweed is the most common and important. In the lower pools this association makes up a very important part in the food supply for waterfowl.

Burreed was present and well distributed, but not too abundant prior to flooding. Since impoundment this species has increased markedly. Shortly after impoundment the burreed-sagittaria association was the dominant emergent association on the refuge, but with the increase in other emergents, together with some reduction in burreed, the association is of lesser importance at the present time. It is still abundant enough, however, to be important for waterfowl cover and for muskrat house-building material.

Rice cutgrass is well distributed on ridges and islands. Locally, extensive marginal stands of this species occur, and since it usually seeds well, it is an important food. In wooded areas another cutgrass (*Leersia lenticularis*) is often more common than is rice cutgrass. Both species are valuable as duck food.

Extensive stands of sagittarias occur, with *S. latifolia* on the semidry margins and shallow water, followed by a zone of *S. arifolia*, and with *S. heterophylla* in beds in deeper water. While these plants are

often found in association with burreed and the bulrushes, there are extensive pure stands in many areas. These plants are important both to waterfowl and muskrats.

Wild rice makes intermittent growth, depending on water conditions, and at the present time there are good stands of rice present in the upper pools. Its ripening habit, together with the presence of myriads of blackbirds, which eat the seed almost as fast as it ripens, reduces its food value for waterfowl, although it is important as cover.

The most common aquatics on the refuge are American pondweed, sago, leafy pondweed, small pondweed, flat-stemmed pondweed, bushy pondweed, curly muckweed, coontail, elodea, water stargrass, wild celery, and the pond lilies.

Perhaps the most abundant species is American pondweed, which is the most important single species of aquatic so far as waterfowl food is concerned. This species occurs in all pools in extensive beds in a great variety of conditions from very shallow water to deep flowing channels. In the upper pools this species grows in such dense beds over extensive areas that boat travel is rendered difficult. It makes its best growth in water 12-30 inches in depth. This species normally is a heavy seeder and is of outstanding importance as waterfowl food.

Sago and flat-stemmed pondweed are also well distributed and abundant, both mixed with other aquatics and in pure stand. Sago ranks a close

second to American pondweed, and has been increasing steadily. Flatstem, on the other hand, has fluctuated up and down, but at this time ranks third among pondweeds, and is often in pure stand over wide areas.

The coontail-elodea association formerly was the most common in ponds and lakes prior to filling of pools. Even after flooding the group was for a time the dominant aquatic association on the refuge. With continued stabilization of water, however, this association has been replaced over wide areas by more important pondweeds. Locally, though, this group is still important.

Naias has increased, and at the present time occurs in pure stand over wide areas. This is especially important for blue-winged teal and baldpate, both of which feed heavily on the beds present.

Wild celery has spread until it can now be found almost the entire length of the refuge. It is most common in the upper pools, however.

So diversified are the aquatics on the refuge that it is not unusual to be able to find more than two dozen species in a matter of minutes anywhere in the better marshes and aquatic beds."

A listing of the aquatic plants of Pools 4-9 is presented in Appendix A.

Wildlife

Mammals

The study area is rich in wildlife species because it provides a variety of mammalian habitats. The most common mammals include three species of shrews, two species of moles, six bats, cottontail rabbit, woodchuck, two ground squirrels, chipmunk, four squirrels, pocket gopher, beaver, nine mice, muskrat, Norway rat, two fox, raccoon, mink, two skunks, and deer. A complete listing of all mammal species is presented in Appendix A (U.S. Dept. Interior, 1968).

At the beginning of the twentieth century the beaver seemed doomed to extinction because of many years of exploitation by trappers, and in 1910 a closed season was declared (Joyce, 1933). Beaver were experimentally introduced at various points in the Upper Mississippi River Wildlife and Fish Refuge during the late 1920's. One small colony established in 1929 had increased to about 100 individuals four years later (Steele, 1933). Beavers are now abundant throughout the refuge.

Flattum (1962) sampled mouse populations from six habitats in Winona County and concluded that upland meadows, upland marsh, and upland woods were much more productive for mice than equivalent areas in the flood plain. Four of the six species caught and 83% of the total mice were taken in the upland areas. The most abundant mouse in flood plain woods was Peromyscus maniculatus, the white-footed deer mouse. The prairie vole, Microtus ochrogaster, was most abundant in flood plain woods.

White tailed deer are common in flood plain areas, particularly where the flood plain borders upland areas. Mattison and Leinecke (1972) found by radio-telemetry that the average home range of deer in the Trempealeau Wildlife Refuge was 118 acres. Deer seem to be especially prevalent on island areas during spring, summer and fall. It is not unusual to find new-born fawns on islands during spring floods. Flood plain forests are heavily used by deer hunters.

Reptiles and Amphibians

Stabilization of the Mississippi River by the 9-foot navigation channel has benefited some aquatic forms of reptiles and amphibians (U.S. Dept. Interior, 1970). The erratic drying of the sloughs of the floodplain has been prevented by the dams. The flood plain affords habitat for seven species of turtles, twelve species of snakes, one lizard, two salamanders, one toad and five frogs. A complete listing of all reptiles and amphibians of the study area is presented in Appendix A.

Dredge spoil deposits are heavily used by soft-shelled turtles (*Trionyx* sp.) as nesting sites (Vose, 1964). The turtles prefer sandy beach areas which are not heavily brushed, but which are not open for more than 15 feet along the shore. Gradually sloping beaches are preferred over steep beaches. Most turtles nest in a zone between 14 and 30 feet from the shore, but one nest was found 121 feet from the water.

Birds

Two hundred and fifty-five birds have been identified in the Upper Mississippi River Wildlife and Fish Refuge since its establisment in 1924 (U.S. Dept. Interior, 1970). Most of these species also occur in the study area. Those species which are most commonly seen in the study area are listed in Appendix A. The birds of greatest importance to the most people are probably waterfowl. Duck hunting is a very important form of recreation throughout the study area.

Fish

The study area contains an extremely varied fish fauna because the river contains so many diversified habitats. Nord (1967) has compiled a comprehensive list of 122 species of fish known to inhabit the Upper Mississippi River. Table VII presents a list of the most commonly caught fish in the study area. Table VIII illustrates the species composition and the size of the catch of commercial fish in the study area.

The study area supports a very productive fishery. Conservatively, the area probably has a carrying capacity of at least 300 pounds of fish per acre. This is attested to by the fact that anglers are allowed to fish year round with two lines for virtually all species of fish.

During the years 1962-1963, an estimated 112,769 anglers spent 424,153 hours fishing in Pool 4 (Nord, 1967). During the same period, an estimated 39,568 anglers spent 157,112 hours fishing in Pool 5. On Memorial Day, 1957 an aerial survey of fishing boats was made. A total of 438 fishing boats were counted in Pool 4, 74 in Pool 5, 111 in Pool 5A, and 52 in Pool 6. An aerial survey of fishing boats on July 4, 1962 tallied 86 in Pool 4, 43 in Pool 5, 38 in Pool 5A and 20 in Pool 6.

Table VII. Fish Species According to Ranking by Numbers in the Creel. Pools 4, 5, 7, 11, 13, 18, and 26, 1962-1963 (Nord, 1967).

RANKING	SPECIES
1	Bluegill
2	Crappie species
3	Channel catfish
4	Whitebass
5	Freshwater drum
6	Sauger
7	Yellow perch
8	Bullhead species
9	Walleye
10	Largemouth bass
11	Carp
12	Northern pike
13	Flathead catfish
14	Other sunfish
15	Smallmouth bass
16	Rock bass
17	Blue catfish
18	Mooneye
19	Sucker species (includes buffalo)
20	Yellow bass

Table VIII Commercial catch of fish in Pounds for 12-year period, 1953-1964 (Nord, 1967).

SPECIES	POOL	TOTAL	12-YEAR AVERAGE
Carp	4	3,279,672	273,306
	4A(Lake Pepin)	14,627,503	1,218,959
	5	1,086,231	90,519
	5A	712,821	59,402
	6	570,528	47,544
Buffalo	4	188,519	15,710
	4A(Lake Pepin)	376,944	31,412
	5	109,612	9,134
	5A	168,921	14,077
	6	178,936	14,911
Fresh-water Drum	4	296,607	24,717
	4A(Lake Pepin)	827,917	68,993
	5	186,255	15,521
	5A	121,687	10,141
	6	73,621	6,135
Catfish	4	138,003	11,500
	4A(Lake Pepin)	284,074	23,673
	5	176,004	14,667
	5A	106,942	8,912
	6	126,730	10,561
Other Species	4	85,749	7,146
	4A(Lake Pepin)	367,343	30,612
	5	139,961	11,633
	5A	43,065	3,589
	6	71,878	5,990

Aquatic Invertebrates

The study area contains a large assemblage of invertebrate species. The varied invertebrate fauna is due to the wide variety of habitats in the area. Lake forms of invertebrates find suitable habitat in the lentic portions of the pools. Organisms which require running water find a wide range of water velocities in the tailwaters, main channel, along the wing dams, and in side channels. The rocks associated with wing dams and shoreline protection provide a suitable substrate for many species. Flood plain pools provide additional habitat for speciallized invertebrates.

The relative abundance of many invertebrates has been changed by the activities of man in the study area. Changes in clam and mayfly abundance, for example, have been well documented. The basic biology of the most abundant caddisflies of the Upper Mississippi River has been reported by Fremling (1960).

Burrowing mayflies are abundant along much of the Mississippi River. Hoardes of emergent insects often cause nuisance problems for river residents, motorists and towboat personnel (Fremling 1960, 1968, 1970). Nymphal forms of the three major species (*Hexagenia bilineata*, *Hexagenia limbata* and *Pentagenia vittigera*) are important food organisms for many species of river fish. The nymphs are efficient converters of detritus to high quality fish food. The abundance of *H. bilineata* and *H. limbata*

has increased by the formation of the silted impoundments associated with the 9-foot channel project (Fremling, 1973). Both species are dependent upon a silted substrate for the construction of their burrows. It is evident from Figures 22 and 23 that the abundance of the *H. bilineata* and *H. limbata* decreases suddenly below St. Louis, the cite of the southernmost dam.

Impoundment and enrichment of the Upper Mississippi River has temporarily increased the carrying capacity of the river for *Hexagenia* mayflies. Pollutants from the Twin Cities have reduced mayfly numbers for 30 miles downstream and also throughout Lake Pepin. The constant loss of silted areas due to the encroachment of sand, however, is the most ominous threat to populations of burrowing mayflies.

Very little is known concerning the biology of *Pentagenia vittigera*, but it is generally assumed to be an inhabitant of the river bottom along the edges of the main channel. It is apparently not dependent upon silted conditions for its existence as are *H. bilineata* and *H. limbata*, thus it is about as abundant at Vicksburg as it is at Keokuk. The scarcity of records just below St. Louis is due to the extremely polluted state of the river in that area. The formation of the 9-foot channel impoundments has apparently not affected the distribution of *P. vittigera* appreciably.

Hemming (1972) sampled *Hexagenia* mayfly populations above and below Lock and Dam 5A to determine the relative abundance and distribution of

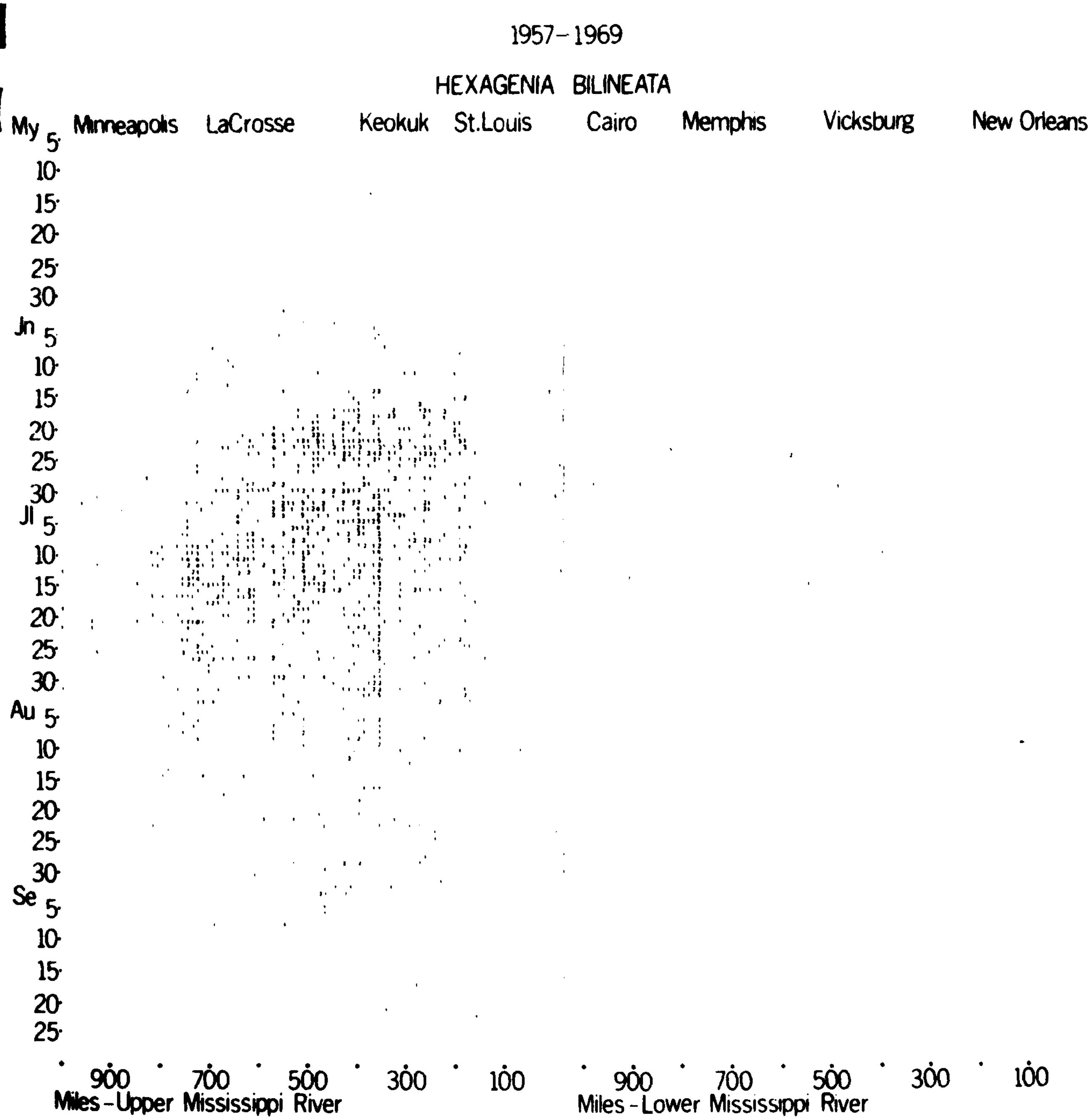

Fig.22. Seasonal and geographical distribution of the mayfly, *Hexagenia bilineata* on the Mississippi River, 1957-1969.

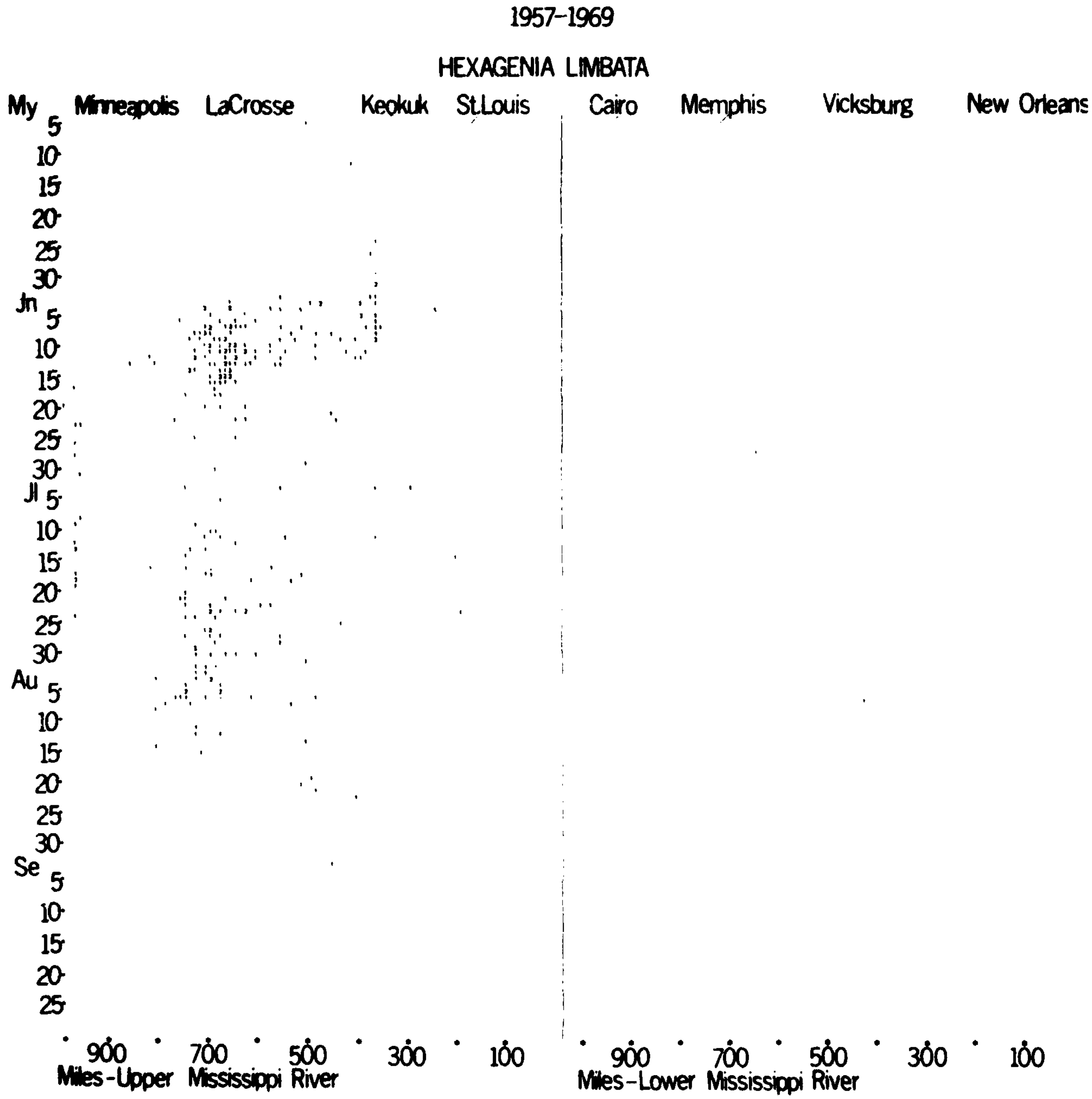

Fig. 23. Seasonal and geographical distribution of the mayfly, Hexagenia limbata, on the Mississippi River, 1957-1969.

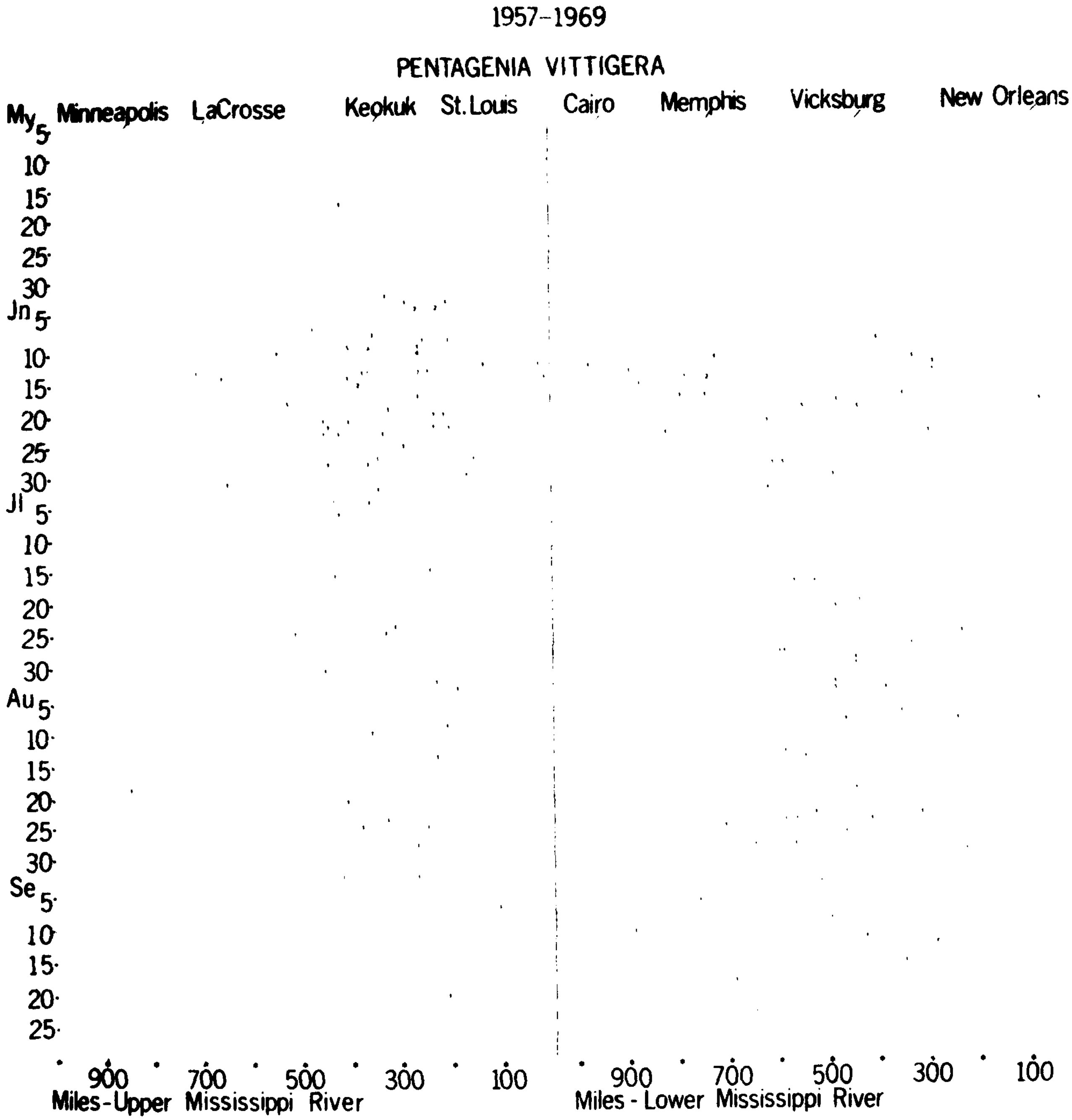

Fig. 24. Seasonal and geographical distribution of the mayfly, Pentagenia vittigera, on the Mississippi River, 1957-1969.

H. bilineata and *H. limbata* as related to environmental conditions. He determined that sand bottoms were always devoid of *Hexagenia* nymphs. This was especially true in the main channel of the river but was true also in backwaters and side channels wherever considerable current kept the bottom free of fine silt. Areas which had a bottom composed of a mixture of sand and silt contained significant mayfly populations. The best habitat in the entire study area, however, was found at the foot of Pool 5A in a silted area known as Polander Lake.

Even within the lake the nymphs were numerous only in certain areas. Those areas which had been former slough areas prior to construction of the dam provided the best habitat. In those areas, deep deposits of silt provided excellent habitat. Old land surfaces, and former islands, now flooded by the dam, did not produce great quantities of nymphs because the substrate was too hard for burrowing. Areas of fine silt where vegetation was found provided no nymphs.

When Lock and Dam 5A was constructed, Straight Slough was bissected by the dam. The portion of the slough which lies above the dam provided excellent *Hexagenia* habitat, but the area below the dam consists of hard clay and sand and no nymphs were found there.

Erickson (1964) sampled Crooked Slough, near Winona, for *Hexagenia* mayfly nymphs. Even though the bottom of the slough was apparently of good texture for mayfly growth, no mayflies were present. He concluded that oxygen deficiencies occurred at the bottom because Crooked Slough

had been isolated from the river by the earthen dike of Lock and Dam 5A. This isolation stopped water circulation within the slough, allowed the slough to stratify and thus precluded the existence of burrowing mayflies.

Mussell fishing began on the Mississippi River in 1889, when the first button factory was started in Muscatine, Iowa (Carlander, 1954; Nord, 1967). Within a decade after the first factory was built, there were signs of exhaustion of the Muscatine clam beds. Two or three years were all that some beds could stand under the intense fishing pressure. The mussel fishery continually extended from its point of origin at Muscatine and by 1899 clamming was the most important fishery in Wisconsin with over 16 million pounds of shells harvested. Lake Pepin produced thousands of tons of shells annually during the first decade of the 20th century.

By the 1930's the mussel industry had virtually died along the Mississippi River. Many factors were at work, but the most important were overfishing, destruction of habitat by pollution and siltation. The innovation of plastic buttons finally ended the pearl button industry on the Mississippi.

Interest in clamming suddenly revived in the early 1960's when a demand appeared for clam shells for the Japanese cultured pearl industry. Mother of pearl nacre from river clams was used to make "seeds" for insertion into salt water oysters. A relatively small clamming business

still operates at various points along the river to supply clam shells to the Japanese.

Today, clam populations are generally sparse along most of the Upper Mississippi River. Navigation dams have slowed down the current, thus allowing silt to cover many of the formerly productive sand beds. Clam populations in Lake Pepin, in particular, have been hard hit. Sludge deposits caused by upstream pollution have virtually eliminated the clam beds of previous years.

Ebert (1965) conducted a seasonal investigation of aquatic macro-invertebrates at the confluence of the Mississippi and Chippewa Rivers in Pool 4. He used modified Hester-Dendy (1962) artificial substrate samplers to collect invertebrates at a sampling station on the Mississippi one mile above the confluence of the two rivers. A second sampling station was located three miles below the confluence and a third station was located one mile up the Chippewa. The invertebrates he collected at the two Mississippi River stations are listed in Appendix . His results indicate generally good water quality at the three stations at all seasons of the year.

Water Quality

Except for Lake Pepin and the upper reaches of Pool 4, the Mississippi River has generally good water quality throughout Pools 4, 5, 5A, and 6. Except in isolated sloughs and backwater lakes, the dissolved oxygen content of the water remains high year round. Because of its turbulent nature, the river is well aerated and it can assimilate a considerable

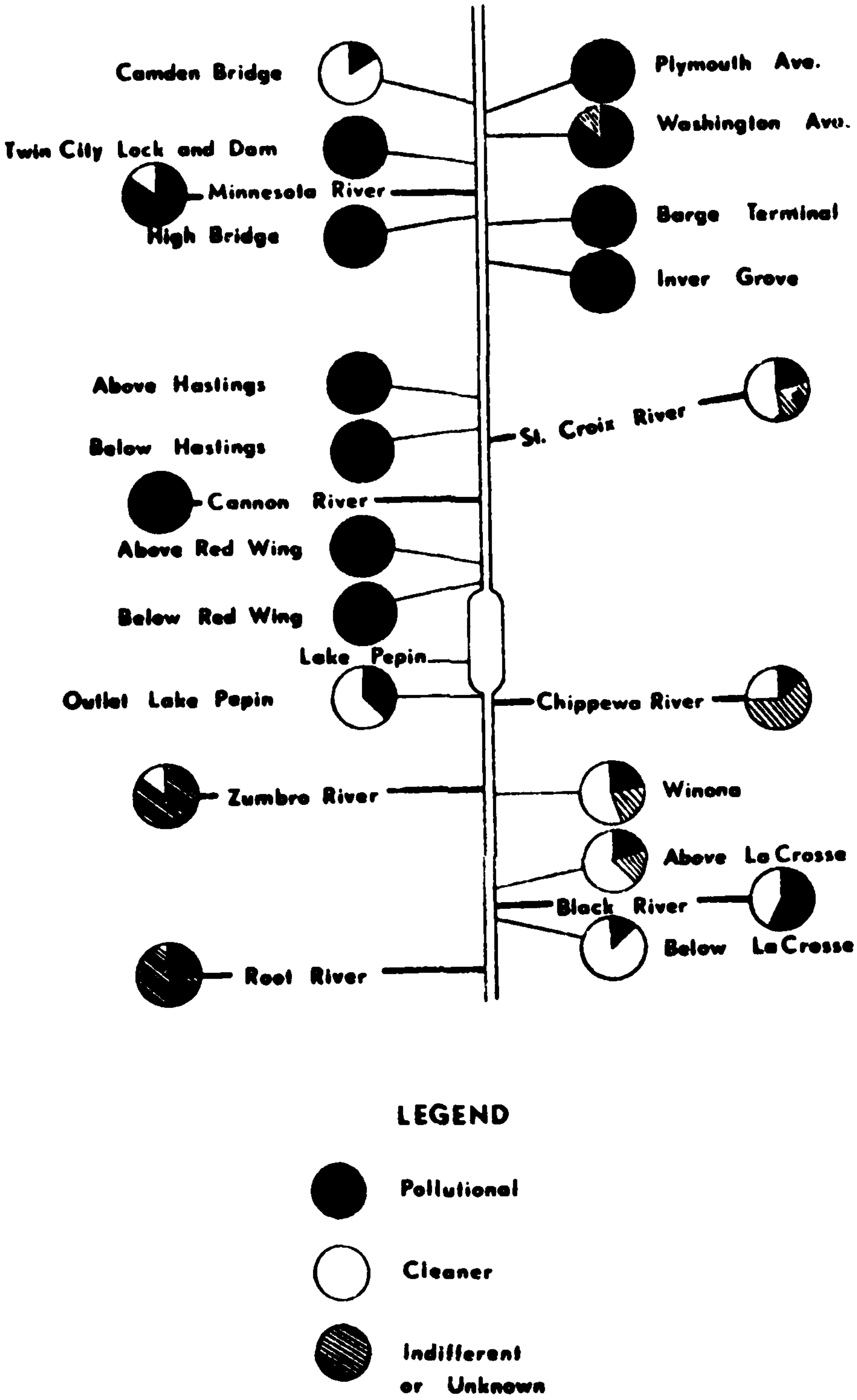

Fig. 25. Ratio between pollutional and clean water organisms at sampling points along the Upper Mississippi River showing a drop in pollution below Lake Pepin. Modified by Watkins (1969) from Minnesota and Wisconsin State Boards of Health, 1928.

B.O.D. loading. Fertility levels (nitrogen, phosphorus, potassium, calcium, etc.) are ample to support luxuriant growth of rooted aquatics and algae.

Lake Pepin was pricipally of organic sludge composition. Although there were often many organisms per square foot of bottom, most of the organisms were pollution tolerant forms. He determined that the entire river segment from Lock and Dam 3 to the mouth of the Chippewa lies in the pollution recovery zone which extends down river from the Twin Cities. A marked improvement in the bacteriological quality of the water was observed during the passage of water through this segment.

Average phytoplankton densities for the period April-December, 1964 were 18,000 per ml at mile 790.6 and 12,000 per ml mile 760.2. Phytoplankton densities were usually very high along the shorelines of Lake Pepin. During the summer of 1965, a greenish algae bloom of pea soup consistency was observed in Lake Pepin at the bathing beach in Stockholm, Wisconsin. Decaying algae created a putrescible odor which attracted hordes of flies. A water sample from the area revealed 12,511,000 blue-green algae per ml with 12,487,000 being Aphanizomenon flosaquae and 24,000 being Anabaena sp. Similar observations were made in 1964 and 1965 at Lake City.

The chlorophyll-a content of plant cells attached to artificial substrates showed that periphyton was about six times as abundant on such substrates in Lake Pepin as on those located upstream. Nutrient concentrations, although more than ample to support luxuriant algae growth, decreased downstream through Lake Pepin.

Benthic organisms found in the 10-mile segment between Lock and Dam 3 and the head of Lake Pepin were all pollution tolerant and ranged in density from 46 to 214 animals per square foot during the fall of 1964. Both the number of animals per square foot and the number of kinds of animals increased downstream through Lake Pepin. The first reappearance of pollution sensitive organisms below the Twin Cities' zone of degradation occurred at mile 784.2, the head of Lake Pepin.

A gelatinous organic sludge bottom, sometimes mixed with organics and silt, covers the bottom of Lake Pepin between mile 784.2 and mile 764.7 (Rademacher, 1965). This bottom supported a large total number of animals (318 to 903 per square foot during the fall of 1964) made up of from 16 to 20 species. Aquatic annelid populations exceeded 100 per square foot at all stations, indicating an organic relatively anaerobic environment. Tendipes midges were also very abundant. They, too, indicated that Lake Pepin acts as a natural settling basin for silt and organic sludges carried in from upstream. Pollution sensitive species, such as unionid clams, mayflies, caddisflies, and riffle bettles, represented less than 50% of the total species and were found only in sandy shoreline areas. Even at the lower end of Lake Pepin (mile 764.7) the total numbers and species of pollution-sensitive animals was far less than in the area upstream from the Twin Cities. Lake Pepin is obviously still within, but near the end of a pollution recovery zone.

The water quality characteristics of the Mississippi River in Pool 4 are presented in Table IX and X for 1964 and 1971.

Table IX . Water Quality Characteristics of the Mississippi River in Pool 4, June-October, 1964 (Rademacher, 1966)

Parameter	Mile 794	Mile 783	Mile 774	Mile 765
Max. Temp. °F	85	-	86	84
Turbidity (J.T.U.)				
Maximum	70	-	25	20
Mean	40	-	10	8
Minimum	20	-	9	5
Dissolved Oxygen (ppm)				
Maximum	10	-	14	13
Mean	7	-	7	7
Minimum	5	-	5	5
BOD (5 day, ppm)				
Maximum	9	-	-	7
Mean	5	-	-	3
Minimum	4	-	-	1
Organic Nitrogen (ppm)				
Maximum	2.1	1.8	-	2.2
Mean	1.7	1.5	-	1.5
Minimum	1.0	1.3		1.0
Ammonia Nitrogen (ppm)				
Maximum	0.9	0.8		0.6
Mean	0.5	0.5		0.2
Minimum	0.2	0.2		0.1
Nitrate Nitrogen (ppm)				
Maximum	0.4	0.3		0.4
Mean	0.2	0.2		0.2
Minimum	0.1	0.1		0.1
Ortho PO_4 (ppm)				
Maximum	0.7	0.6		0.6
Mean	0.5	0.55		0.55
Minimum	0.4	0.5		0.5
Total Coliform (MPN/100 ml)				
Maximum	45,000	3,000		1,000
Mean	20,000	300		300
Minimum	350	20		200

Table X. Summary of Water Chemistry Data Collected in 1971 at Northern State Power Co. Prairie Island Nuclear Generating Plant Located at the Extreme Lower End of Pool 3 (Northern States Power, 1972)

Analysis in mg/l		1971 Minimum	1971 Maximum	1971 Average	1970 Minimum	1970 Maximum	1970 Average
Solids	Total	222.6	357.5	289.0	240	396	307
	Dissolved	213.0	355.5	278.5	241	366	279
	Suspended	1.4	42.6	10.4	2	73	29
Hardness (as $CaCO_3$)	Total	148	256	196	176	268	198
	Calcium	96.0	172.0	129.7	118	180	130
	Magnesium	52.0	84.0	67.1	56		69
Alkalinity (as $CaCO_3$)	Total	105.0	192.0	152.4	116	184	157
	Phenolphthalein	0	0	0	0	12	2
Gases	Ammonia Nitrogen, N	0.08	0.93	0.49	0	1.0	0.37
Anions	Chloride (Cl)	5.34	32.90	15.62	5	20	14
	Nitrate Nitrogen, N	0.60	2.45	1.10	0.03	3.6	0.9
	Sulfate (SO_4)	35.0	80.0	46.0	33	70	45
	Phosphorus (Soluble), P	0.082	0.230	0.155	0.09	0.33	0.17
	Silica, SiO_2	7.2	14.3	11.4	3	12	8
Cations	Sodium, Na	7.0	28.5	13.7	9	18	13
	Total Iron, Fe	0.11	0.66	0.36	0.3	2.2	0.8
Miscellaneous	Color, APHA Units	35.0	90.0	66.4	20	100	50
	Turbidity, JTU	2.8	20.0	7.1	3	40	16
	Ryznar Index at 77°F	7.07	8.54	7.44	6.3	7.8	7.2
	Conductivity, mmhos	308.0	572.0	423.8	351	540	407
	pH	7.40	8.15	7.72	7.5	8.7	7.9

Biological and Chemical Observations made in 1973

A series of transects was established throughout the study area during the spring and summer of 1973. A detailed description of each transect is provided in Appendix Table 24. Maps showing the locations of transects are presented in Appendix Figures 32-37. The purpose of the transects was to provide comparative sampling locations within pools and between pools. Moreover, sampling sites were selected along each transect so that the sites could be located again in future years for baseline comparisons of flora, fauna and physical parameters. Two Ponar dredge samples were taken at each station and the pooled contents were washed through No. 40 soil seives to separate out the contained invertebrate animals. In rocky areas where dredging was impossible, samples were obtained by swimming to pick up rocks. Depth measurements were made at each sampling site and the bottom type was examined and recorded. Except with extremely difficult groups, such as chironomid midge larvae, invertebrate animals were identified to species. These data are recorded in Tables 12 - . A key to taxonomic categories and bottom types is presented in Table 11 .

Water quality measurements were made at each sampling site and at various other sites. The parameters included temperature, pH, Secchi disk transparency, dissolved oxygen, total hardness, calcium hardness, alkalinity, nitrate, ammonium nitrogen, organic phosphate, inorganic phosphate, ortho phosphate and total phosphate. Chemical and temperature

determinations were made with Hach chemical kits, colorimeter and a Hydrolab IIA electronic temperature and dissolved oxygen meter. Chemical and temperature data are presented in Tables 13 and 14.

It is apparent from the data contained in Tables 11 - 12 that the study area affords a rich and varied invertebrate fauna. It is obvious that the most productive areas are: (1) silted bottoms which are well-oxygenated by flowing water, and (2) the rock rubble which composes wing dams and shoreline protection. The later substrate provides a great surface area. It, like the silt bottom, however, is productive only as long as it is bathed by oxygen-rich water. The most barren substrate is sand. The sandy bottom of the navigation channel is especially unproductive. Other relatively unproductive areas include the bottoms of thermally stratified flood plain lakes, the depths of which usually become anaerobic during the summer.

The water chemistry measurements reveal that the river throughout the study area is very fertile and that it is capable of supporting large populations of algae, rooted aquatic plants, invertebrate animals and fish. It must be remembered, however, that such a fertile body of water contributed large volumes of organic sediment to the backwaters. The organic sediment has a high biochemical oxygen demand and it can cause conditions of oxygen depletion at the mud-water interface and in the hypolimnion of thermally stratified flood plain sloughs which have been stagnated by barrier islands of dredge spoil. Furthermore, the organic sediment decomposes very slowly under anaerobic conditions.

Table 11. Key to symbols used for recording taxonomic status of benthos and type of bottom at sample sites along transects within the study area.

Phylum

I – Annelida
II – Arthropoda
III – Mollusca
IV – Pisces

Class

A – Hirudinea
B – Oligochaeta
C – Arachnoidea
D – Eucrustacea
E – Insecta
F – Gastropoda
G – Pelecypoda

Order

1 – Rhyncobdella
2 – Opisthopora
3 – Plesiopora
4 – Amphipoda
5 – Cladocera
6 – Isopoda
7 – Coleoptera
8 – Diptera
9 – Ephemeroptera
10 – Hemiptera
11 – Odonata
12 – Plecoptera
13 – Trichoptera
14 – Hydracarina
15 – Ctenobranchiata
16 – Pulmonata

Family

a – Sphaeriidae
b – Glossiphonidae
c – Haplotaxidae
d – Tubificidae
e – Talitridae
f – Daphnidae
g – Leptodoridae
h – Asellidae
i – Dytiscidae
j – Elmidae
k – Ceratopogonidae
l – Chironomidae
m – Culicidae
n – Baetiscidae
o – Caenidae
p – Ephemerellidae
q – Ephemeridae
r – Heptageniidae
s – Corixidae
t – Hydropsychidae
u – Psychomyiidae
v – Perlidae
w – Coenagrionidae
x – Gomphidae
y – Hydracarinidae
z – Pleuroceridae
a' – Valvatidae
b' – Physidae
c' – Planorbidae
d' – Piscicolidae
e' – Limnaeidae
f' – Leptoceridae

Substrate

c – clay
d – detritus
gr – gravel
m – mud
oo – organic ooze
r – rocks
s – sand
shf – shell fragments

Misc.

Tr. – trace, less than 0.001 gms/m^2.

Table 12. Benthic fauna and bottom type found at sampling stations along transects within Pool 4.

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/12/73	4VV	1	I,B,3,d	*Limnodrilus* sp.	1	Tr.	s
			II,E,8	Chironomidae sp.	1	0.038	
		2	I,B,3,d	*Branchiura sowerbyi*	1	0.699	oo,c
			II,E,9,q	*Hexagenia* sp.	2	2.42	
			II,E,8	Chironomidae sp.	4	0.151	
		4	I,B,3,d	*Limnodrilus* sp.	5	0.189	oo
			II,E,8	Chironomidae sp.	22	0.624	
			II,E,8,m	*Chaoborus* sp.	16.	0.472	
7/12/73	4WW	1	I,B,3,d	*Branchiura sowerbyi*	1	0.284	c,d
			II,E,9,q	*Hexagenia* sp.	1	1.777	
			I,B,3,d	*Limnodrilus* sp.	1	0.567	
			II,E,8	Chironomidae sp.	1	0.132	
		2	II,E,8	Chironomidae sp.	1	0.019	s,m
		3	I,B,3,d	*Branchiura sowerbyi*	8	0.227	oo
			II,E,8	Chironomidae sp.	1	Tr.	
		4	II,E,8,m	*Chaoborus* sp.	2	0.038	oc,d
			I,B,3,d	*Limnodrilus* sp.	21	2.004	

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/12/73	4WW	5	I,B,3,d	Limnodrilus sp.	80	2.949	oo
			II,E,8,m	Chaoborus sp.	1	0.038	
			III,G,a	Musculium sp.	1	1.153	
7/12/73	4XX	1	II,D,6,h	Lirceus sp.	1	Tr.	s,d
			II,E,8	Chironomidae sp.	1	0.0378	
			II,D,5,f	Daphnia sp.	1	Tr.	
			II,E,8,k	Palpomyia sp.	1	0.094	
			II,D,5,g	Leptodora kindtii			
			I,B,2,c	Haplotaxis sp.	1	0.17	
			I,B,3,d	Limnodrilus sp.	9	0.34	
			I,B,3,d	Branchiura sowerbyi	1	0.813	
		2	I,B,3,d	Limnodrilus sp.	71	2.96	oo,d,shf
			II,E,8	Chironomidae sp.	18	6.087	
			III,G,a	Sphaerium sp.	1	1.09	
			I,B,3,d	Branchiura sowerbyi	3	3.40	
			II,E,8,m	Chaoborus sp.	1	0.057	
		3	II,E,8	Chironomidae sp.	17	5.40	oo,d,shf

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/12/73	4XX	3	III,G,a	*Sphaerium* sp.	1	0.132	oo,d,shf
			III,G,a	*Musculium* sp.	1	1.72	
			I,B,3,d	*Limnodrilus* sp.	117	3.404	
			II,E,8,m	*Chaoborus* sp.	6	0.265	
			II,D,5,f	*Daphnia* sp.	5	0.38	
			I,B,3,d	*Branchiura sowerbyi*	4	1.72	
			II,D,5,g	*Leptodora kindtii*	7	0.227	
		4	III,G,a	*Sphaerium* sp.	8	0.098	oo,d,shf
			II,D,5,f	*Daphnia* sp.	40	0.019	
			I,B,3,d	*Branchiura sowerbyi*	25	0.071	
			II,E,8	Chironomidae sp.	32	0.765	
			I,B,3,d	*Limnodrilus* sp.	4	0.007	
			II,D,5,g	*Leptodora kindtii*	21	0.07	
			II,E,8,m	*Chaoborus* sp.	16	0.05	
7/11/73	4YY	1	I,B,3,d	*Branchiura sowerbyi*	4	0.623	m,d
			II,E,8,k	*Palpomyia* sp.	1	0.038	
			II,E,8	Chironomidae sp.	12	0.926	

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/11/73	4YY	1	I,B,3,d	*Limnodrilus* sp.	2	0.454	m,d
		2	I,B,3,d	*Branchiura sowerbyi*	8	2.079	oo
			I,B,3,d	*Limnodrilus* sp.	55	2.873	
			II,E,8,k	*Palpomyia* sp.	1	Tr.	
			II,E,8	Chironomidae sp.	23	5.879	
		3	II,E,8	Chironomidae sp.	1	0.454	oo
			II,D,5,f	*Daphnia* sp.	9	0.038	
			I,B,3,d	*Branchiura sowerbyi*	21	3.421	
			I,B,3,d	*Limnodrilus* sp.	1	0.473	
			II,E,8,m	*Chaoborus* sp.	1	0.095	
		4	II,D,5,f	*Daphnia* sp.	5	0.737	oo
			II,E,8	Chironomidae sp.	29	5.577	
			II,E,8,k	*Palpomyia* sp.	1	0.019	
			I,B,3,d	*Limnodrilus* sp.	7	0.359	
7/11/73	4ZZ	1	II,D,6,h	*Lirceus* sp.	4	0.321	oo
			II,E,8,m	*Chaoborus* sp.	2	0.095	
			I,B,3,d	*Branchiura sowerbyi*	5	5.671	

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/11/73	4ZZ	1	II,E,7	Dytiscidae sp.	1	Tr.	oo
			III,G,a	Sphaerium sp.	3	0.397	
			II,E,8	Chironomidae sp.	7	0.378	
			II,E,9,q	Hexagenia sp.	11	30.907	
		2	II,E,8	Chironomidae sp.	3	0.151	oo,d
			III,G,a	Sphaerium sp.	6	0.286	
			III,G,a	Musculium ap.	3	1.304	
			II,D,6,h	Lirceus sp.	1	0.151	
			I,B,3,d	Limnodrilus sp.	1	Tr.	
			II,E,9,q	Hexagenia sp.	9	29.053	
		3	I,B,3,d	Branchiura sowerbyi	1	0.945	s,oo,d
			II,E,9,o	Brachycercus sp.	1	0.208	
			III,G,a	Pisidium sp.	2	0.189	
			III,G,a	Sphaerium sp.	2	1.342	
			II,E,9,q	Hexagenia sp.	1	0.567	
			II,E,8	Chironomidae sp.	1	0.095	
		4	II,E,8	Chironomidae sp.	10	0.17	s,d

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
7/11/73	4ZZ	4	I,B,3,d	_Limnodrilus_ sp.	2	Tr.	s,d
			III,G,a	_Sphaerium_ sp.	1	1.323	
			II,E,9,q	_Hexagenia_ sp.	1	0.435	
			II,E,9,o	_Brachycercus_ sp.	2	0.284	
		5	II,D,5,f	_Daphnia_ sp.	1	Tr.	S.
			II,E,8	Chironomidae sp.	5	0.038	
			III,F,16,b'	_Physa_ sp.	1	0.208	
		6	II,E,8,m	_Chaoborus_ sp.	2	0.151	m,d
			I,B,2,c	_Haplotaxis_ sp.	94	1.512	
			II,D,5,q	_Leptodora kindtii_	1	Tr.	
		7	II,E,8	Chironomidae sp.	8	0.567	s,oo
			II,D,5,q	_Leptodora kindtii_	1	Tr.	
			I,B,3,d	_Limnodrilus_ sp.	3	0.189	
			III,G,a	_Sphaerium_ sp.			
6/29/73	4CC	1	II,E,9,q	_Hexagenia_ sp.	3	8.979	m,d
			II,E,8	Chironomidae sp.	1	0.057	
			III,G,a	_Sphaerium_ sp.	2	0.51	

Table 12. (cont.)

Date	Transect	Station	Taxa code	Species	No.	g/m^2 (wet wt.)	Bottom
6/29/73	4CC	1	III,G,a	_Musculium_ sp.	2	0.51	m,d
			III,F,16,e'	_Stagnicola_ sp.	1	0.265	
			II,D,6,h	_Lirceus_ sp.	1	0.019	
		2	III,G,15,a'	_Valvata sincera_	1	0.17	m,s,d
			II,E,9,q	_Hexagenia_ sp.	1	1.115	
			III,G,15,a'	_Valvata tricarinata_	1	0.227	
			III,G,a	_Musculium_ sp.	1	0.208	
		3	II,E,9,q	_Hexagenia_ sp.	1	0.132	m,s,d
		4	II,E,8	Chironomidae sp.	1	Tr.	s
		5	II,E,8	Chironomidae sp.	1	0.019	s
			II, E,9,q	_Hexagenia_ sp.	1	0.019	

TABLE 13. Water quality characteristics of the Mississippi River at various sites in Pools 4, 5, 5A and 6. Unless otherwise indicated, all measurements given in ppm.

Date	Transect	Station	Depth (ft.)	Temp. (°C)	pH	Secchi disk (in.)	D.O.	Total hardness	Calcium hardness	Alkalinity	Nitrate
7/12/73	4vv	4	0.5	26.1	9.5	10	12	187	85	119	0
7/12/73	4xx	4	0.5	23.7	8.0	39	11	221	119	187	1.0
7/11/73	4yy	1	0.5	28	9.0	44	16	238	136	170	1.2
7/11/73	4zz	5	0.5	22.2	8.5	33	12	238	119	119	0.6
			16.5	20			8				
		7	0.5	25.5	8.5	21	13	187	85	136	0.4
			18	20			7				
6/29/73	4cc	2	0.5	34		16	8.2	238	119	170	2.0
			6	33			8.1				
		6	0.5	33	8.0	12	8.3	204	68	85	1.0
6/26/73	5AA	1	0.5	23.3	8.5	11	9	255	119	170	0
			3				7				
		2	0.5	25.5	8.5	15	12	289	136	170	1.0
			4	22.2			7				
6/25/73	5BB	3	0.5	23.3	8.0	11	10	238	119	153	1.0
		8	0.5	22.2	8.0	20.5	10	238	109	153	0.9
6/25/73	5CC	2	0.5	23.3	8.0	19.5	10	238	109	136	1.0
6/22/73	5AAA	4	0.5	18.8	8.0	23	10	238	108	136	0.7

TABLE 13. (continued)

Date	Transect	Station	Depth (ft.)	Temp. (°C)	pH	Secchi disk (in.)	D.O.	Total hardness	Calcium hardness	Alkalinity	Nitrate
6/21/73	5ABB	10	0.5	20	8.0	23	10	238	109	153	1.0
6/15/73	5ACC	1	0.5	22.2	8.5	25	10	221	102	170	0
6/15/73	6AA	1	0.5	22.2	8.5	19	11	208	119	136	0
6/13/73	6BB	5	0.5		8.5	23	13,5	316	136	136	0.9
6/13/73	6CC	6	0.5		8	23	10	238	136	170	0.9

TABLE 14. Water Quality Characteristics of the Mississippi River at various sites in Pools 4, 5, 5A and 6, August 9 and 10, 1973. Unless otherwise indicated, all measurements given in ppm. Samples and temperatures taken 6 in. below surface of water in main channel.

Pool	Mile	Temp. (°C)	pH	Secchi disk (in.)	D.O.	Total Hardness	Calcium hardness	Alkalinity	Nitrate	Ammonium nitrate	Phosphate			
											Organic	Inorganic	Ortho-	Total
4	789	29.1	8.25	19	12.5	238	119	187	0.4	0.7	0.68	0.5	0.46	1.18
4	785	26.1	9.0	28.5	11	238	102	187	0.2	0.3	0.58	0.3	0.3	0.88
4	774	26.1	9.25	32	10.5	187	153	153	0.3	0.3	0.7	0.55	0.36	1.25
4	763	23.3	9.0	31	10	153	119	153	0.3	0.3	0.7	0.58	0.43	1.3
5	753	26.1	8.0	24	11	238	102	153	0.2	0.3	0.65	0.41	0.35	1.06
5	739	23.3	8.75	17	11	238	136	153	0.3	0.4	0.6	0.4	0.31	1.03
5A	733	23.3	8.5	22	11	238	85	170	0.1	0.35	0.5	0.54	0.47	1.04
6	726	23.3	9.0	20	11	187	85	140	0.2	0.4	1.4	0.56	0.45	1.96
6	715	26.7	9.0	22	11	238	102	153	0.2	0.4	0.67	0.61	0.43	1.28

Endangered Species

Bald Eagle

The northern bald eagle, though not in an endangered status, like the southern form, is subject to the same forces that could decimate its numbers farther. Several concentration points exist where the northern bald eagle feeds and rests during its sojourn on the Upper Mississippi River. The southern bald eagle has been identified here by banding records.

Pool 4

That area from the Alma Dam (L/D4) to the foot of Lake Pepin is valuable as a feeding area where fish are available in the open water between those points. The greatest concentration can be found in the immediate vicinity of the mouth of the Chippewa River.

Pool 5

Early in the fall until freeze up, the bald eagle gathers in the Weaver Bottoms, drawn there by the number of wounded waterfowl that are concentrated in the closed area.

Pools 5A and 6

Lesser numbers use these pools as there is little open water where food can be taken. It is common to see bald eagles soaring along the bluffs during winter months.

Peregrine Falcon

This bird, once plentiful along the river is now seldom seen and

is in a rare status. It was common to see numbers of those fine birds both spring and fall when waterfowl were migrating, but none have been recorded for several years.

Osprey

The Osprey has declined markedly in numbers along the river over the past several years. There were nests recorded in the past but no nests have been seen here for many years.

Double Crested Cormorant

This bird formerly traversed the Mississippi flyway in huge flocks during spring and fall migrations. Since the early 1960's however, the numbers have dropped to a few sightings of very small flocks.

Lake Sturgeon

This species is in the rare status with no estimate of its numbers in the Mississippi River available. Commercial fishermen and sport fishermen fishing below the dams take occasional speciments.

Indiana Myotis Bat

This small bat has not been identified within Pools 4, 5, 5A or 6. Because of its very small numbers and limits of its range to southern Wisconsin it may not ever have more than a rare visitor.

SOCIOECONOMIC SETTING

The socioeconomic aspects of the environmental setting are discussed (1) by identifying the three-way subdivision of socioeconomic activities used in this report and (2) by presenting an overview of these activities in Pool 4 as they also relate to the Northern Section of the Upper Mississippi River.

Three Subdivisions of Socioeconomic Activities

It is useful to divide a discussion of the socioeconomic setting of the study area of the Upper Mississippi River into (1) industrial activity, (2) recreational activity, and (3) cultural considerations.

Industrial Activity

Industrial activity includes agricultural, manufacturing, transportation, and related pursuits that affect employment and income in the study area directly; this includes employment on farms, in barge operations, commercial dock facilities, lock and dam operations, commercial fishing and trapping. While it is probably most desirable to measure industrial activity in terms of jobs or dollars generated, lack of available data makes this impossible in the present study. As a result indices of this industrial activity — such as tons of commodities moved, industrial facilities constructed, or pounds of fish caught — are generally used.

Recreational Activity

Recreational activity has two effects of interest. One is the psychological value to the users themselves of being near or on the Mississippi River for leisure activities. A second effect is the impact of the recreational activity on employment and income. Recreational activity is more indirect in its effect on employment and income than is industrial activity and relates mainly to leisure-time activities of people using the Mississippi River for recreational purposes; examples include boating, sport fishing, hunting, sightseeing, camping, and picnicking. Recreational activities frequently use units of measurement like number of boaters or fishermen using a lake or river, fishing licenses sold, or visitor-days. It is often very difficult to find such measures for a particular pool on the Mississippi River. Where such data are available — such a pleasure boat lockages — they are used. Where they are not available — such as fishermen using a specific pool — proxy measurements are used; for example, number of sport fishermen observed annually by lock and dam attendants are taken as a measure of fishing activity in the pools — even though this is not as precise a measure as desired. Problems involved with placing dollar values on these recreational activities are discussed in Section 6.

Cultural Considerations

Cultural considerations are the third component of the socioeconomic setting. These considerations include three kinds of sites of value to

society: archaeological sites, historic sites, and contemporary sites. These sites can include such diverse physical assets as burial mounds, historical battlegrounds or buildings, or existing settlements of ethnic groups such as Amish communities. Because of the difficulty of placing any kind of value on such sites, they are simply inventoried in the present study.

Overview of Socioeconomic Activities in the Study Area

The industrial, recreational, and cultural aspects of Pool 4 are discussed below in relation to the entire Northern Section of the Upper Mississippi River to provide a background with which to analyze the impact of operating and maintaining the 9-foot channel in Section 3 of this report.

Industrial Activity

The existence of the Mississippi River and its tributaries has had a profound effect on the industrial development of the American Middle West. It has served as a route of easy access for transportation and communication tying together the industrialized East with the agricultural Middle West as well as the varied economies of the North and South.

Historical Development of the Waterway The development of the Northern Section of the Upper Mississippi as a waterway for shipment has paralleled the rise of the American economy, keeping pace with the need to move bulk raw materials and heavy, high-volume commodities over the wide

geographical areas served by the river network. This has allowed barge transportation to remain competitive with other forms of transportation. It is noteworthy that competing systems of land transportation such as railroads and highway trucking utilize the relatively gentle river valley terrain in order to simplify both engineering design and fuel energy demands. Thus, the Mississippi River Valley is intensively utilized to meet the transportation needs of the Midwest.

Long before the coming of the first white settlers, the Mississippi River was a transportation corridor for the Indians. It was used to facilitate the primitive barter economy and as a route for other forms of social and cultural communication and contact.

In its primitive condition, the Upper Mississippi was characterized by numerous rapids and rock obstructions. Fluctuations in water flow during various seasons of the year were minor inconveniences to the Indian canoe, but demanded modification before substantial commercial use of the river could take place. Prior to improvements, such traffic was limited to periods of high water when log rafts and small boats could pass between the Falls of St. Anthony and the mouth of the Ohio River.

The necessity of modifying the natural course of the river to make it suitable for commercial navigation gradually became apparent as the size of the river boats and barges grew. Since the first river steamboat arrived at Fort Snelling in 1823 and steamboat transportation for freight and passenger use grew to a peak in the decade 1850 to 1860 when over

1000 steamboats were active on the entire length of the river. By 1880 the growth of the railroad system in the U. S. and the lack of a channel of sufficient depth marked a decline in the use of the river for transportation. However, on the upper reaches of the Mississippi, growth in freight traffic continued. A peak was reached in 1903 with 4.5 million tons moved between St. Paul and the mouth of the Missouri River. A subsequent rapid decline coincided with a drop in river use for moving logs and lumber. In 1916 only 0.5 million tons were shipped on this section of the river.

As the population and industry of the Upper Midwest region grew, there was a corresponding growth in the need for cheap coal for power generation. A technological consequence of this need was the development of the barge and towboat which gradually replaced the steamboat on the river. The barge and towboat required a deeper channel than the earlier steamboats. The need for coal in the Upper Midwest was complemented by the need to ship large quantities of grain south to other centers of population. Thus, economies were realized by having at least partially compensating cargoes going both directions on the upper reaches of the river. In the later 1920's large grain shipments from Minneapolis began.

Although $4\frac{1}{2}$-foot and 6-foot channels had been authorized in recognition of the increasing role of the river in the transportation network of the U. S., technological developments in barges and towboats led to the authorization of a 9-foot channel to Minneapolis in 1930. By 1940 the channel and the requisite locks and dams were essentially complete.

When figures for tonnages shipped at various times on the Mississippi River are examined, it is difficult to make comparisons that relate to Corps' activities. For example, the following factors complicate the problem of data analysis during the period to 1940:

1. Statistical data collected by the Corps of Engineers covered different segments of the Upper Mississippi River during these years. Some of the reasons for this appear to be changes in the administration of river segments during that time, as well as some experimentation with better methods of statistical collection.

2. Shipping in the Upper Mississippi was distorted during the decade of the 1930's due to the construction of locks and dams in the St. Paul District.

3. From 1941 to 1945 all forms of transportation were utilized for the war effort without regard to maximizing economic return. Therefore, data for these years (as with the 1930's) does not necessarily reflect a normal period of transportation on the Upper Mississippi.

Barge Shipments Table 15 shows tonnage information available for selected years from 1920 through 1945 for the river segment identified in the third column of the table.

Table 15 . River Shipment from 1920 through 1945.

Source: Comparative Statement on Barge Traffic,
U.S. Army Corps of Engineers.

Year	Total Tonnage (short tons) Shipments and Receipts*	River Segment
1920	630,951	Mpls. to Mouth of Missouri River
1925	908,005	Mpls. to Mouth of Missouri River
1926	691,637	Mpls. to Mouth of Missouri River
1927	715,110	Mpls. to Mouth of Missouri River
1928	21,632	Mpls. to Mouth of Wisconsin River
1929	1,390,262	Mpls. to Mouth of Ohio River
1930	1,395,855	Mpls. to Mouth of Ohio River
1935	188,613	St. Paul District
1940	1,097,971	St. Paul District
1945	1,263,993	St. Paul District

*Tonnages exclude ferry freight (cars and other) and certain cargoes-transit.

In more recent years, data are available for the St. Paul District. Table 16 shows the movement of tonnages through the St. Paul District for the years from 1962 through 1971.

Table 16. River Shipment from 1962 through 1971.

Source: Comparative Statement on Barge Traffic, U.S. Army Corps of Engineers.

Year	Total Traffic St. Paul District
1962	8,168,594
1963	9,266,361
1964	9,621,336
1965	9,205,538
1966	11,346,457
1967	11,618,849
1968	10,736,350
1969	12,647,428
1970	15,423,713
1971	15,070,082
1972 (estimated)	16,361,174

When this table is compared with the previous one, the growth of shipping on the Upper Mississippi becomes readily apparent. Thus, the total traffic for the St. Paul District in 1962 was about six times the traffic in 1945, which was a war year. In fact, traffic in the St. Paul District for 1962 was more than five times greater than all of the traffic on the Upper Mississippi between Minneapolis and the Mouth of the Ohio River in 1930. Traffic about doubled in the St. Paul District between 1962 and 1971. This was due to a large degree to grain shipments from the District and to an increase in receipts of coal.

In 1928 data were collected on receipts and shipments for the river segment from Minneapolis to the mouth of the Wisconsin River. This approximates the navigable segment of the Upper Mississippi within the St. Paul District, and the data for this segment can be equated with data for the St. Paul District with little difficulty. In that year, 21,600 tons were received and shipped. By 1940, tonnages handled reached 1,000,000 tons annually, when the lock and dam system and the nine-foot channel were virtually complete. Tonnages reached 2,000,000 by 1946, and 3,000,000 by 1953. By 1962 over 8,000,000 tons were shipped and received in the St. Paul District. In the decade between 1962 and 1972 this had doubled to 16,000,000 tons.

Table 17 shows the number of trips made on the Mississippi between Minneapolis and the mouth of the Missouri River in 1971.

Table 17. River Trips in 1971. Source: Waterborne Commerce of the United States Calendar Year 1971, U. S. Corps of Engineers.

Transportation Mode	Upbound	Downbound
Self Propelled		
Passenger & dry cargo	1,900	1,875
Tanker	3	2
Towboat or Tugboat	8,433	8,419
Non-Self Propelled (barge)		
Dry cargo	25,250	25,237
Tanker	7,312	7,311
TOTAL	42,898	42,844

Commercial Dock facilities To accommodate the barge traffic on the Upper Mississippi River, many firms maintain commercial docks. Some of these have elaborate facilities for loading or unloading specialized cargoes with which they deal—coal, oil, grain, and gravel and crushed rock. The facilities vary appreciably with individual pools. Pool 4 has 5 commerical docks transhipping grain, coal and miscellaneous freight. Those serving the firms in the area covered by this report will be discussed later in Section 3 under "Socioeconomic Systems".

An indication of the "thoroughfare" function that Pool 4 provides for barge traffic in the study are the commercial lockages through all locks in the Northern Section that are shown in Figure 26. These also provide another indication of the recent increase in barge traffic. From 1960 to 1972 the number of lockages in the portion of the River between Lock and Dam 2 and Lock and Dam 10 increased by about 600, the increase that was also present in Pool 4.

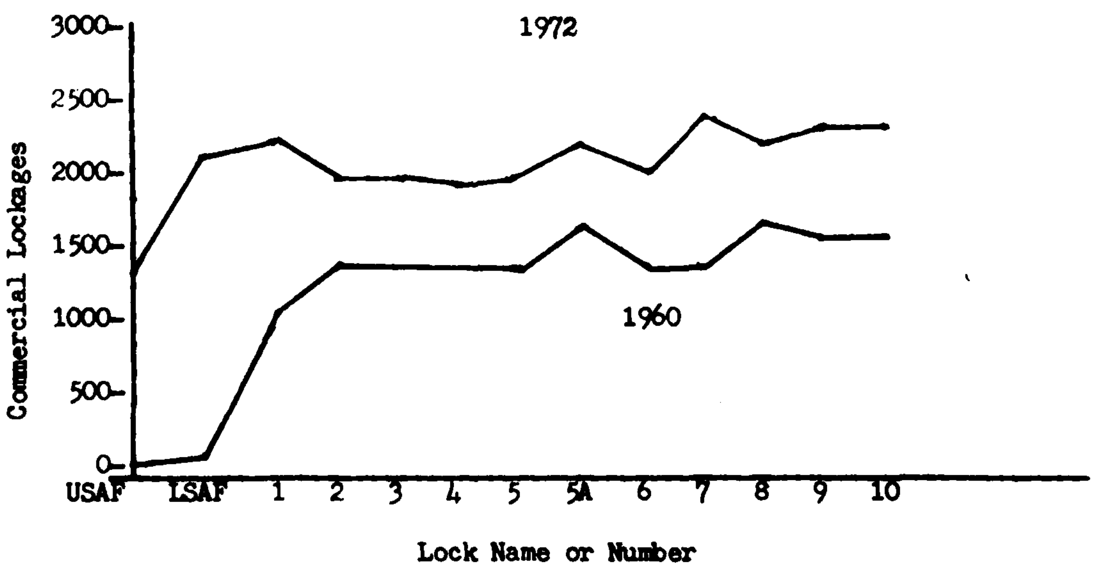

Figure 26. Commercial Lockages in Upper Mississippi River in 1960 and 1972. Source: St. Paul District of the U.S. Army Corps of Engineers, Annual Lockage Data, 1960 and 1972.

The shipping season for most of the Mississippi River within the St. Paul District is usually 8 months, from mid-April to mid-December. The navigable rivers maintained and operated by the St. Paul District should be viewed within the context of the system as a whole including the Mississippi, Ohio, Missouri and other tributary rivers. In 1964 a detailed analysis of origin-destination waterborne commerce traffic patterns showed that the average miles per ton on the Upper Mississippi River Waterway System ranged from 700 to 800 miles. This indicates that the great bulk of shipments and receipts have origins or destinations outside the St. Paul District. Each pool, then, in addition to its own shipments and receipts, contributes to the economic benefits enjoyed by the system as a whole. Thus, any measure of the economic benefits of the river commerce on an individual pool must include the benefits that it contributes as a necessary link in the Upper Mississippi system.

Commercial Fishing and Trapping. As population along the Northern Section of the Mississippi River increased, industrial specialization also took place. The result was the development and growth of commercial fishing and trapping along the Upper Mississippi in the last half of the nineteenth century and during the twentieth century.

Limited data are available on the extent of commercial fishing and trapping prior to 1930. However, the rise in the water level behind the newly -constructed locks and dams in the Upper Mississippi River after 1930 increased marsh development and provided more fish, fur-animal

habitat over that existing prior to the construction.

Data on commercial fishing in the 1960's in the pools in the study area are shown in Figure 27. In 1969 the Northern Section of the Upper Mississippi River produced about 5.5 million pounds of fish that were sold commercially; this was an increase of about 9 percent from the 1960 total. The commercial value of the fish caught in 1969 was about $400,000.

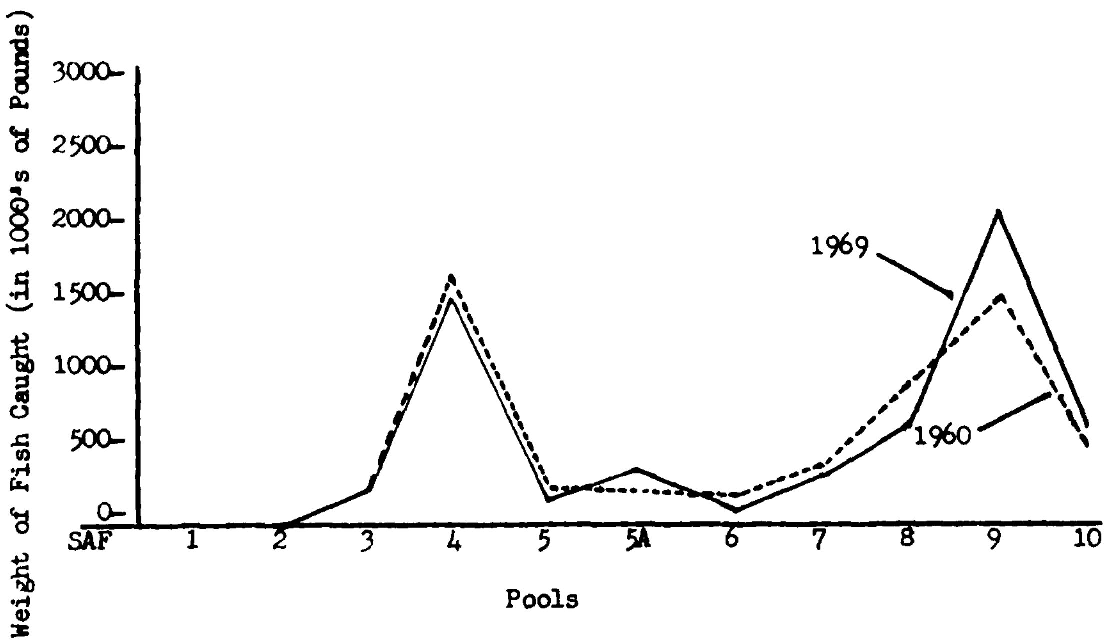

Figure 27. Thousands of Pounds of Fish Caught Annually by Commercial Fishermen in Upper Mississippi River Pools in 1960 and 1969. Source: UMRCC. Proceedings of Annual Meeting, 1962 and 1971.

Figure 27 shows that the bulk of the commercial fishing in the pools in the study area — about 4.8 million pounds of fish and 86 percent of the total — occurred in Pools 4, 8, 9, and 10. Pool 4 is a major contributor, with 1.5 million pounds in 1969.

Trapping data have been collected for the past three decades by the Upper Mississippi River Wildlife and Fish Refuge, which is managed by Bureau of Sport Fisheries and Wildlife of The U.S. Department of the Interior. This refuge was established by Congress in 1924 and runs for 284 miles along the Upper Mississippi River from about Wabasha, Minnesota to above Rock Island, Illinois — or from approximately Lock and Dam 4 to Lock and Dam 13. Between 1940 and 1970 an average of 748 trappers per year obtained trapping permits. Between 1940 and 1970 25,000 beavers and over 2.25 million muskrats were trapped whose furs averaged nearly $100,000 annually (Green, 1970). By the 1971-72 season, the price of muskrat pelts was over $1.00 and the annual harvest was valued at about $200,000.

Forest Management

The following is excerpted from the Forest Management Plan of the Winona District (Pools 4, south of Chippewa River 5, 5A and 6) Upper Mississippi River Wildlife and Fish Refuge, 1969:

Pool 4 has3975 acres of forested land under the ownership of the federal government. The management of this forest will be done to benefit the wildlife, recreational and economic values of the land in the best possible manner.

The forest will be managed for wildlife purposes. Openings will be created to produce edge effect for the benefit of wildlife. Cavity trees and den trees will be maintained in the stand as will be mast or food producing species.

With the river being a high recreational attraction emphasis on forest management must also lean in this direction. A canoe route has its southern terminus at Winona, thus to keep an air of primitiveness about this route and all other water activity, buffer zones will be used to screen all logging operations. All major river islands are exempt from cutting because of their great recreational potential.

When setting up a timber sale, then, more than the economic return must be considered. The whole spectrum of land use in that particular area will be examined in terms of use now and in the future.

The management plan shows that on the 3975 acres of forest land in the Pool there is available 22,315,000 boardfeet of saw timber and 30,000 cords of pulpwood.

Recreational Activity

In addition to the industrial described above, the Northern Section of the Upper Mississippi River has provided innumerable recreational opportunities for the entire region it serves. Even prior to Congressional authorization of the 4-1/2-foot channel in 1878—the first comprehensive project on the Upper Mississippi, from the mouth of the Ohio River to St. Paul—settlers used the river extensively. The Upper Mississippi provided settlers the opportunity to boat, fish, hunt, and sightsee. However, the need for these settlers to carve out an existence in the Minnesota wilderness of the early nineteenth century meant that recreational uses of the upper River were few. Thus, boating then was not for recreational purposes; it was essential for the settlers' continuing

existence to move people and supplies to where they were needed. Similarly hunting and fishing were not for sport; they provided the food needed to feed the settlers' families; surplus fish or game were sold or traded for other necessities required for daily living.

As the twentieth century dawned, leisure time accompanying the settlers' higher standard of living led to recreational uses of the Upper Mississippi River. Segregating present-day recreational uses of the study area due to Corps' operations from those existing in 1930, prior to the 9-foot channel, presents problems. These arise because of the difficulty of isolating the increased recreational uses of the river caused by more people in the region, higher standards of living, and increased leisure from those caused by improved navigational and other recreational opportunities.

A significant portion of the recreational activity on the Upper Mississippi is due (1) to the improved navigation opportunities for pleasure craft of all sizes and drafts, because of stabilized higher water levels, the well-marked main channel and some side channels, (2) the attractiveness of the "sandbars" formed by dredge spoil disposal along the main channel, even though access is usually limited to boats, and (3) to increased fish and game habitat resulting from higher water levels in the river.

The potential for improved fishing and hunting has not always been realized because of (1) sedimentation started almost immediately upon the establishment of the slack water pools, (2) dredging activities

contributed to the sedimentation rate as well as actually covering fish spawning grounds, slough openings onto the main channel, and covering wildlife feeding and breeding grounds, and (3) increased industrialization along the river has caused pollution that decimated some fishing and hunting areas as well as rendering some fish inedible because of unpleasant taste picked up from pollutants.

Boating Activity and Related Facilities As noted above, much of the increased boating in the study area of the river — and virtually all of it for the deeper-draft pleasure boats — is made possible by the improved navigational opportunities provided by the system of locks and dams. Figure 28 illustrates the dramatic growth in pleasure boating in the study area from 1960 to 1972. The figure shows that number of pleasure boats moving through each lock in the study area increased by an average of about 1,500 boats during the twelve-year period. It can be seen that the number of pleasure boats moving through Locks 3 and 4, those at each end of Pool 4, increased by a greater than average amount for the District during this period. This is attributable to the passage of pleasure boats into Lake Pepin which has greater boating opportunities than most other sections of the river. The proximity of Lake Pepin to the Twin Cities and its large number of boaters is a significant factor in the large number shown in Figure 28 for Lock and Dam 3.

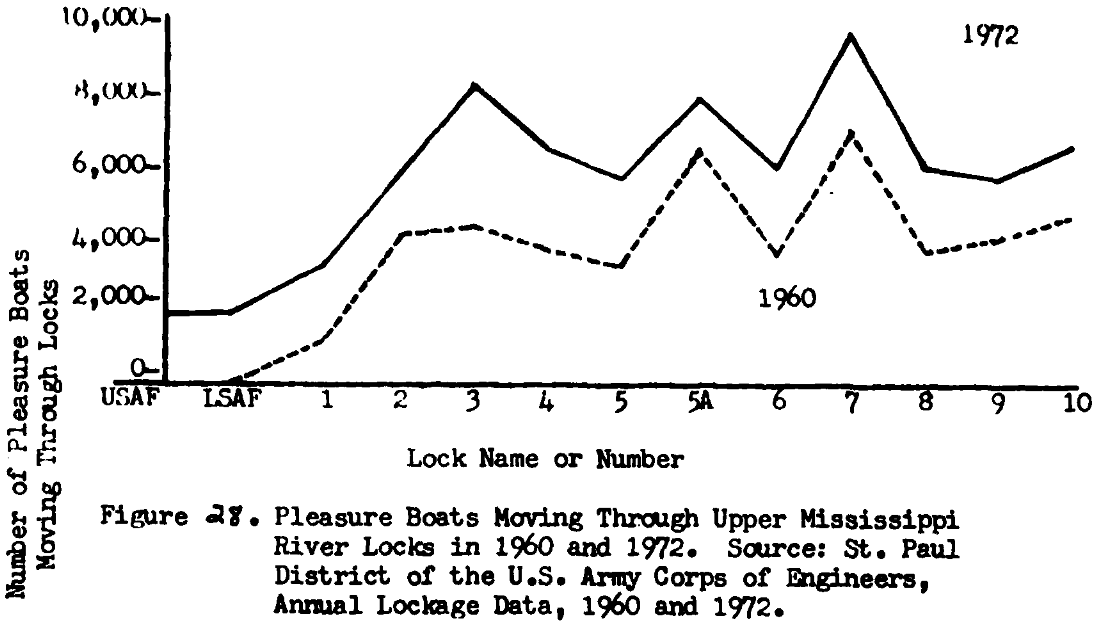

Figure 28. Pleasure Boats Moving Through Upper Mississippi River Locks in 1960 and 1972. Source: St. Paul District of the U.S. Army Corps of Engineers, Annual Lockage Data, 1960 and 1972.

A variety of facilities have been developed in Pool 4 mainly to serve the pleasure boaters. These include numberous small boat harbors, marinas, and boat clubs—as well as recreational sites and restaurants. Table shows the major public use facilities as of 1968 (St. Paul District, June 1968). Access to the waters of Pool 4 from both shores is excellent. The Federal Government owns the land on which 7 of these facilities are located, state governments own 2 and county and municipal governments 12. One is owned by a sportmen's club. Six of the small boat harbors were developed by the Corps of Engineers although they are owned and managed by others.

Perrot State Park, a 1396-acre recreational area operated by the Wisconsin Department of Natural Resources (Mile 716) provides numerous and varied opportunities for visitors to enjoy the Mississippi River.

Boat launching ramps and parking areas provide access to the water for boating and related activities such as hunting and fishing, while several miles of trails along the river and to the bluff tops offer unparalleled scenic vistas of the great expanse of waters from Trempealeau, Wisconsin to Winona, Minnesota.

Sport Fishing and Hunting Precise measure of the number of sport fishermen using each specific pool in the study area are not available. Perhaps the only comparable data for all pools are the number of sport fishermen observed annually by attendants at lock and dam sites. Attendants to each lock and dam observed the river pool areas above and below their site at 3:00 p.m. each day and record the number of sport fishermen seen; the annual data are simply a sum of these daily estimates.

Sport fishery survey data for two years, 1962-63 and 1967-68, are also available for Pool 4. These are summarized in Table and show that the number of fish caught in Pool 4 increased by about 13% from 1962-63 to 1967-68. In the same period the number of fishing trips increased by 50 percent in Pool 4, from about 113,000 to 169,000.

Sport hunting of waterfowl along the Mississippi River study area is large. It is estimated that in 1963, the year for which the most precise data are available, hunters made about 2,600 visits to Pool 4. The Winona District of the Upper Mississippi River Wildlife and Fish Refuge (which covers Pools 4, 5, 5A, and 6) estimates that for the ten years from 1961 to 1970 an average of 12,035 hunters in the District bagged an average of 15,600 waterfowl annually.

Table 18. Result of two sport Fishery surveys on Pool 4, 1962-63 and 1967-68.
Source: The 1962-63 data are from Robert C. Nord, The 1962-63 Sport Fishery Survey of the Upper Mississippi River (LaCrosse, Wicosnin: Upper Mississippi Conservation Committee; October 6, 1964). The 1967-68 data are from Kenneth J. Wright, The 1967-68 Sport Fishery Survey of the Upper Mississippi River (LaCrosse, Wisconsin: Upper Mississippi Conservation Committee, October 1, 1970).

Measure of Comparison	1962-63	1967-68
Projected number of fishing hours annually	424,153	575,230
% breakdown of fishing hours:		
a. Boat	55%	53%
b. Bank	12	15
c. Barge	18	7
d. Ice	15	25
Total	100%	100%
% breakdown of fish chiefly sought		
a. Walleye and sauger	36%	45%
b. Bluegill, crappie, and sunfish	36	22
c. Northern pike	5	4
d. Other	23	29
Total	100%	100%
Project breakdown of Fish caught annually (in fish)		
a. Walleye and sauger	59,000 fish	129,000 fish
b. Bluegill, crappie, and sunfish	161,000	159,000
c. Northern pike	4,000	10,000
d. Other	116,000	96,000
Total	340,000 fish	384,000 fish
Catch rates (Fish caught per man-hour)		
a. Boat	0.767	0.595
b. Bank	0.806	0.619
c. Barge	0.735	0.269
d. Ice	1.011	0.960
Annual Average	0.802	0.667
Estimated annual recreational value:		
a. Fishing trips	112,769	169,000
b. Value at $1.50 per trip	$169,154	$254,042

The number of sport fishermen observed by attendants at each lock and dam in the study area are shown in Figure 29 for the years 1960 and 1970. There has been little change during the ten-year period of the number of sport fishermen observed. Because fish tend to seek water with a high concentration of dissolved oxygen and the dams tend to aerate the water, the bulk of the sport fishermen tabulated in Figure 29 are probably in the pool downstream from the lock and dam cited on the horizontal axis of the figure. The figure shows that in 1970 about 6,000 fishermen were observed from Lock and Dam 3, most of them fishing in Pool 4.

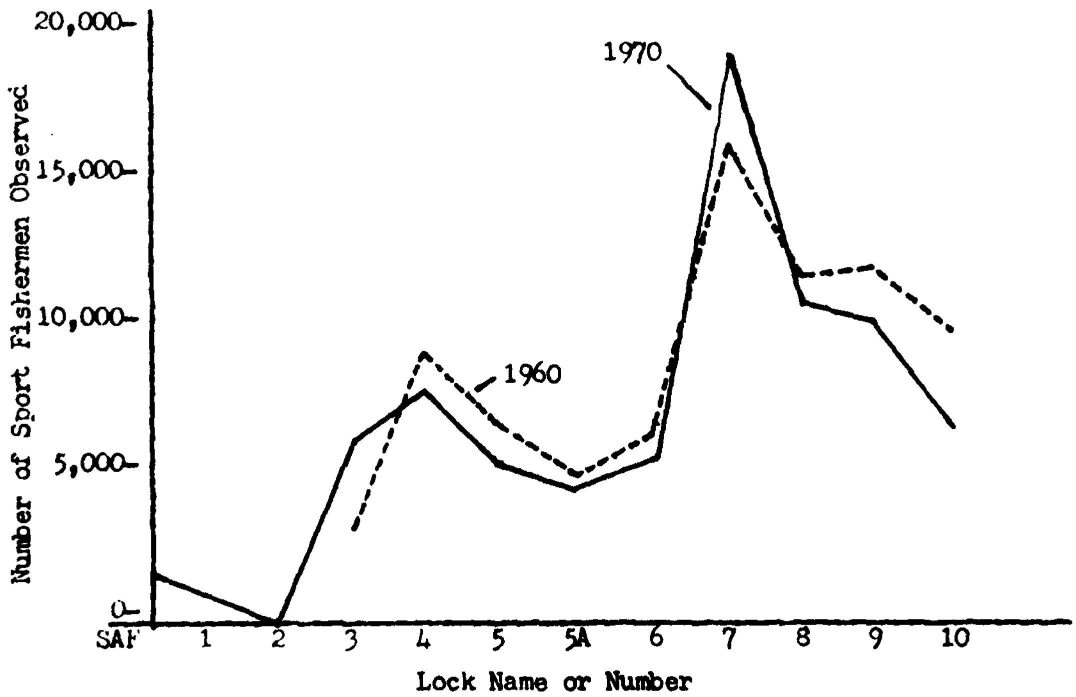

Figure 29. Number of Sport Fishermen Observed Annually by Attendants from Lock and Dam Sites on the Upper Mississippi River in 1960 and 1970. Source: UMRCC, Proceedings of Annual Meeting, 1962 and 1971.

Sightseeing and Picnicking Studies in general indicate that a body of water is often essential for most recreation activities. People want this water not only to boat on or to fish or swim in, but also simply to look at, picnic beside, and walk along. The study area of the Upper Mississippi has served this purpose for settlers for two centuries. Again, because precise data are lacking, it is generally difficult to isolate the effect of Corps' operations on recreational activities such as sightseeing, picnicking, and hiking. To assist sightseers, the Corps of Engineers operates eight overlooks at locks and dams in the study area. In addition, a variety of parks exist along the river that are available for sightseeing and other recreational activities.

Cultural Considerations

A number of archaeological, historical, and contemporary sites exist in the study area. No such sites in Pool 4 are known to have been affected by operations of the Corps of Engineers.

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3. ENVIRONMENTAL IMPACT OF THE PROJECT

INTRODUCTION

The major impacts due to the 9-foot channel project can be divided between: (1) the maintenance activities and operation by the Corps of Engineers and, (2) construction of the locks and dams.

Many of the externalities associated with channel modification on the Upper Mississippi River are beneficial. Wing dams and closing dams have, in effect, corrugated the river bottom, thus increasing its surface area. The limestone rubble of the structures provides an excellent substrate for the growth of invertebrate animals. In addition to thus providing food for fishes, the wing dams and closing dams have provided additional habitat for fishes.

The locks and dams have also had beneficial effects. By impounding the river, they have increased the water surace per linear mile of river, thus increasing the total photosynthetic area of the river. As a consequence, the river now produces many times more pounds of fish per linear mile than it did before the impoundment. Moreover, the tailwaters of the dams are virtual food lots for fish. The fish which congregate in the tailwaters of a dam receive food produced in the huge expanse of the impoundment above. Not only have the dams provided more fish, they have also concentrated the fish so that they may be harvested more efficiently.

The navigation dams have increased waterfowl habitat and made pleasure boating possible. The sand from dredging has provided beautiful beaches.

Unfortunately, there are adverse externalities associated with channel modification. These must be discussed also.

It is obvious to most observers that wing dams, closing dams, and impoundment-producing dams have caused sand and silt to accumulate in the flood plain. The navigation pools are filling at an alarming rate with an attendant loss of water surface, fish habitat, game habitat, and boating areas.

Leopold (1964) has documented the fact that any obstruction in a stream which lessens the stream's competence will promote deposition. Following the closure of a dam, sedimentation begins. Usually, sedimentation can be expected to continue until the sediment level throughout most of the pool reaches the crest of the spillway of the dam. Bed level can be expected to be raised upstream to the point at which the water surface of the reservoir intersects the original bed.

Some investigators feel that as vegetation develops on deposited sediments, the effect of the reservoir will be felt progressively upstream even beyond the aforementioned point of intersection. Other investigators have presented conflicting evidence. Various studies show that fill is occuring on the Upper Mississippi in areas immediately downstream from dams. The conversion of much of the flood plain from prairie to flood plain forest may be responsible, in part, for this.

An obstruction placed in the flood plain of the river increases the rate of aggradation of the river bed. The rate of aggradation of the flood plain of the Upper Mississippi was increased by the early channel improvement structures. The rate has been

further increased by the dams associated with the 9-foot channel. Increased elevation of the flood plain may be attended by increased flood crests, but this has not been fully documented and the increase in flood crests may be negligible.

The following is primarily a listing of the most obvious impacts resulting from the project. Most of the impacts are a matter of degree and, at present, few objective appraisals can be made as to the magnitude of the impacts. It is obvious, however, that after seeing primarily beneficial impacts of the project for 40 years, we are beginning to see serious, long term, perhaps irreversible detrimental impacts.

NATURAL SYSTEMS

Identification of Impacts

Impacts resulting from the project are due to: 1) construction of wing dams, closing dams and shoreline protection associated with the 4½-foot, 6-foot and 9-foot channel projects; 2) construction of locks, dams and earthen dikes; 3) impoundment of the river and the subsequent stabilization of water levels; 4) operation of the locks and dams; 5) construction and maintenance of navigation assistance structures such as channel markers; 6) dredging and the consequent creation of dredge spoil deposits; and 7) operation of commercial craft, pleasure boats and U.S. Coast Guard vessels.

The following is a listing and discussion of the beneficial and detrimental impacts associated with the project. It must be recognized,

however, that "beneficial" and "detrimental" are relative terms and are usually judged from a human view point. Things that are beneficial for man are not necessarily beneficial for other species.

Beneficial Impacts

The 9-foot project, by dedicating almost 100% of the lands in the river bottoms to public ownership and control, brought to fruition a long sought dream of conservationists from all walks of life for the preservation of the bottom lands as a haven for wildlife and fishes. It also made the lands available for all times to lawful and legitimate public use, the foremost of which has been for general recreation.

The Upper Mississippi River Wild Life and Fish Refuge Act of June, 1924 authorized the Department of Agriculture to purchase the bottom lands of the Mississippi River from Wabasha, Minnesota to Rock Island, Illinois. A limit of $5.00 per acre was put on the Department of Agriculture for land purchase. The limit was later raised to $10.00 per acre, but by 1930 when the navigation project became a reality, only 80,000 acres in a scattered pattern had been purchased. In the pattern of ownership, little in the way of efficient management could be initiated. When the Corps of Engineers began buying bottom lands not already in federal ownership for the 9-foot channel project, the Department of Agriculture stopped buying land. In return for use of the Department of Agriculture land for impoundment purposes, the Corps agreed to make its lands available for refuge purposes. Without the 9-foot channel project it is doubtful if the Upper Mississippi River Wild Life and Fish Refuge would be the

great conservation area it is today.

The project removed farming operations from a high risk area. Crop production, haying and grazing were always subject to flooding, and access was often difficult or impossible in high water. Consequently, flood plain farming operations were submarginal at best.

Prior to the project, a large-scale program of fish rescue was carried out each year. The rescue work was made necessary by fluctuating water levels which caused fish to be stranded in flood plain pools. Stabilization of water levels made this work unnecessary.

Complete federal ownership of bottom lands permits efficient designation of sanctuaries and open hunting areas to the welfare of migratory waterfowl populations during the hunting season.

Complete federal ownership of the bottom lands assures the continued free use of the area by the public. In an era when "no trespassing" signs are becoming increasingly prevalent, it is refreshing to know that such signs will not appear in the Mississippi River Refuge, and 9-foot navigation project lands and waters.

Federal control of the bottom lands restricts, but does not completely eliminate private and industrial exploitation of the lands. It is separate from indiscriminate development, however, in that application for such uses must be made to the appropriate federal agency, said agency then able to judge each request on its merits and effect upon the environment.

The existence of the pools has led to greater cooperation between state natural resource departments, enabling the states to manage fish and wildlife resources more efficiently. The present impoundments usually extend to the railroad tracks which flank the river on either side. The tracks serve as easily recognized boundaries to the area of fishing recipocity which lies between Minnesota and Wisconsin.

The huge expanses of water in the impoundments have improved the scenery of the area. Prior to the project much less water area was visible to river residents and motorists.

The locks and dams in the project area are very impressive structures and most people enjoy viewing them. Many people also enjoy watching tows pass through the locks. The play of spot lights and the sound of amplified radio messages are very dramatic and exciting. The viewing stands at the locks are heavily patonized by visitors from most of the 50 states and many foreign countries.

The sight of a modern towboat with a full complement of barges lends much in beauty and contrast to the naturalness of the river setting.

Dredge spoil has created beautiful sand beaches along the main channel of the river. Because of their proximity to navigable water, the beaches are heavily utilized, free of charge, by the public for swimming, picnicking, water skiing and camping.

The 9-foot channel project has enchanced the opportunities for boating on the river. It is unlikely that water skiing, for example, would be

as popular under natural river conditions. The inundated bottom lands presently offer a labyrinth of channels and back water lakes which are available to pleasure boaters, fishermen and hunters.

Navigation impoundments have increased the total surface area of the river, thus increasing the space available for aquatic life and also increasing the area available for photosynthetic activity. Upstream pollution sources have supplied nutrients to the river. As a consequence of these activities, there are undoubtedly more pounds of fish per linear mile of river now than there were before the white man came to the area. The river probably contains in excess of 800 pounds of fish per acre. Most fisheries biologists consider this to be a conservative estimate. (Lake Winona, eutrophic a floodplain lake, was poisoned during the summer of 1973 and the lake contained 747 pounds of fish per acre). Because the river is so productive, sport fishermen are able to fish year around, with two lines, for most river fish. Catch limits are more liberal in most instances than they are in inland waters. The great commercial catch of fish in the area is due also to the 9-foot project.

The pool areas of the river act as food production zones and the tailwaters of the dams serve as feeding zones for many species of fish. The tailwaters create a "feed lot" situation where fish congregate and are thus more easily caught.

The rock rubble found in wing dams, closing dams and shoreline protection devices provides excellent substrate for the growth of

invertebrate animals. Because of their location in the current and because the water which flows over them is nutrient-rich and well-oxygenated, the wing dams are extremely rich in species and total numbers of invertebrates. The wing dams effectively increase the total area of river bottom for invertebrate production. The wing dams create artificial riffle areas- which are the most effective areas in any stream for the production of fish food. The wing dams, closing dams and rip-rap have created habitat which is necessary to some species of fish, especially the small mouth bass. Wing dams provide areas where fish congregate and are thus more easily harvested by fishermen.

Hexagenia mayflies thrive in areas where there is a silt bottom and well-oxygenated water. The navigation pools provide such habitat, and there is no doubt that the mayfly population of the study area has increased because of the project. The insects are a nuisance to most people and the increase in the mayfly population may be considered to be detrimental. The insects are excellent fish food organisms, however, and their abundance is reflected in the abundance of fish in the area.

Increased water areas have caused populations of valuable fur bearers, such as muskrat and beaver, to increase. In addition to being valuable monetarily, the animals provide a distinct recreational resource for trappers.

The navigation pools serve, to a degree, as sewage treatment facilities. The dam at Hastings, for example, creates a huge sewage lagoon below St. Paul. After the sewage receives primary and secondary treatment in the sewage plants of the metropolitan area, it is lagooned by the Hastings dam. Here, decomposition of some of its pollutant load

occurs. As the sewage goes through the roller gates of the dam it is aerated somewhat. Continuing downstream, it is impounded behind each succeeding dam so that it receives additional treatment as it proceeds down the river.

Detrimental Impacts

Spoil deposits are often placed by the dredge at the nearest available point to reduce costs. This has been detrimental to marsh areas which have become covered with sand. The sand may flow directly into the marsh from the discharge pipe, or it may be carried there by normal currents, floods or by the wind. Slough openings have been closed and spawning beds and food producing areas have been covered with sterile sand. Many acres of forest have been killed or stunted by the deposits. The above changes are continual, accumulative and, in most cases, irreversible.

Many channels of the river have been intercepted by dikes and especially by barrier islands created by dredge spoil. Such channels stagnate in the summer and the deeper ones stratify thermally. The rich organic ooze which collects on the bottom consumes oxygen from the lower stratum of water until it becomes a death zone. Most forms of life, clams included, fail to live in such areas. Because of the lack of circulation in such areas, organic matter accumulates rapidly on the bottom under anaerobic conditions. The isolated channels, which have become extremely rich eutrophic lakes, now have bottoms consisting of deep desposits of unproductive organic ooze.

Figure 30 . U.S.D.A. photograph showing the Drury Island area (mile 760-763) near Wabasha, MN. in 1939. Note the obvious wing dams and small dredge spoil deposits. Compare with Fig.30a.

Figure 30a. 1965 U.S.D.A. photograph showing same area as in Fig. 30 . Note that most wing dams are now covered with dredge spoil.

Wing dams and closing dams which were inundated by the 9-foot channel project are navigation hazards. They are usually unmarked and they usually lie about propellor deep beneath the water.

The system of priorities for passage through the locks is a distinct disadvantage to the recreational users of the river. Two-hour waits for lock passage are not uncommon. The situation is especially bad on busy week ends and holidays. It is very likely that citizen groups will file suite against the Corps with the next few years over this issue.

The indiscriminate use of large trees as mooring posts by tow boats has caused girdling and uprooting of many trees.

The Corps of Engineers does not have a sound recreation management plan for its lands and has dedicated but small amounts of its total budget for public benefit. An example of this is the total disregard of the need for management of the ever-popular sandbars resulting from dredging to maintain the 9-foot channel. Until the Upper Mississippi Refuge took it upon itself to protect the public from sanitation problems and safety hazards caused by deposition of litter by users, no concern had been evidenced by the Corps. Further, no attention currently is being paid to this problem that is outgrowing the capabilities of the refuge personnel to handle. This is a distinct detrimental impact of the project that has assumed major proportions.

Increased volume of commercial traffic on the river has increased the chances for oil spills to occur. Spills of other poisonous materials such as anhydrous ammonia are also possible.

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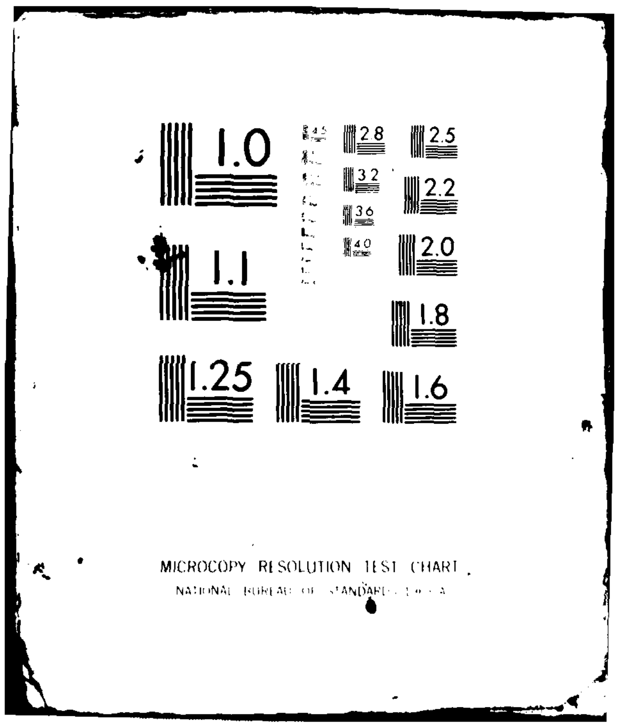
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SOCIOECONOMIC SYSTEMS

Specific impacts of Corps' operations on the subdivisions of socioeconomic systems for Pool 4 are identified below and then discussed in detail.

Identification of Impacts

The impacts on the socioeconomic systems related to the study area of the Upper Mississippi River divide into the industrial, recreational and cultural effects.

Industrial Impacts

In contrast to some pools in the study area that have had considerable industrialization along their banks, Pool 4 has had comparatively little and is the origin or destination of only a minor portion of the commodities that move through the pool. The result is that the industrial impacts of operating and maintaining the 9-foot channel in Pool 4 have been limited. The principal industrial impacts are:

1. Some increase in employment as a result of the 5 commercial docks located in Pool 4.
2. Increased turbidity of water in some portions of the Upper Mississippi River due to barge movement.
3. Additional employment due to the operation of Lock and Dam 4.
4. An initial increase in commercial fishing and trapping because higher water levels caused increased acreage of suitable fish and fur-bearer habitat. More recently, a potential decline in commercial fishing because recent dredge spoil placement has reduced suitable fish habitat.

To summarize, beneficial industrial impacts that result from operating and maintaining the 9-foot channel and its associated locks and dams by the Corps of Engineers are the through-traffic link for commodities moving up and down the river, the employment in lock and dam and commercial dock operations, and an initial increase in the potential for commercial fishing and trapping. The detrimental effects are a decline in water quality due to river barge movement and - with continued loosely planned dredge spoil placement - a likely decline in commercial fishing.

Recreactional Impacts

1. An increase in recreational boating due to stable, navigable water levels which leads directly to more recreation facilities — and their accompanying employment.

2. An immediate increase in sport hunting and fishing due to an increase in —

   a. Waterfowl habitat, and

   b. Fish spawning areas resulting from rising water levels

   Again, as with commercial fishing cited above, dredge spoil placement has recently had a detrimental effect on sport hunting and fishing.

3. An increase in sightseeing visitors to the locks and dams at both ends of the pool.

Cultural Impacts

No archaeological, historical, or contemporary sites of cultural significance in Pool 4 are known to have been affected by Corps' operations.

Discussion of Impacts

The industrial, recreational and cultural impacts identified above are examined in detail in the following three sections. Resource implications of these three socioeconomic impacts are disucssed in Section 6.

Industrial Activities

The economic effect of the activities of the Corps of Engineers on the Mississippi River in the St. Paul District can be measured mainly in terms of three major elements. They are:

1. The channel itself with its associated locks and dams and navigational aids;
2. The installations at riverside for the transfer of cargo, storage facilities, and access;
3. The vessels using the waterway.

In these terms the impact of the Corps' activities in Pool 4 is not as great as in some of the other pools in the Northern Section of the Upper Mississippi River.

Barge Activity The greatest and most obvious impact of the activities of the Corps of Engineers in Pool 4 has been the modification of the transportation system due to the growth of barge traffic. The visual evidence of the impact is seen in the physical structures (e.g., locks and dams, and the 5 commercial dock and terminals) on the shore and the barge tows moving along the river. However, Pool 4 has not been the origin or terminal for most of the commodities that move in barges

along the Upper Mississippi River. Rather, it serves as an important water link between major commodity terminals upstream and downstream from it.

Figures 31 and 32 show graphically the growth of receipts into and shipments from the St. Paul District in the 30 years from 1940 to 1970. Commodities shown in the figures illustrate the diverse economic activity within the St. Paul District; this diversity is less true of Pool 4 whose commercial docks handle coal, grain, and miscellaneous freight. However, the vast bulk of the commodities shown in Figures and flow through the pool enroute elsewhere. Although receipts in the St. Paul District still substantially exceed shipments, the growth in shipments (89 percent grain) from the district in these three decades indicates the great impact of the river on the regional economy.

In 1970 some rough projections (based on 1964 data) were made of the growth of commerce in the St. Paul District (UMREBS, Study Appendix J, 1970). The projections suggest that the tonnage of barge traffic moved in the Upper Mississippi River basin will about double from 1964 to 1980 and about triple from 1964 to 2000.

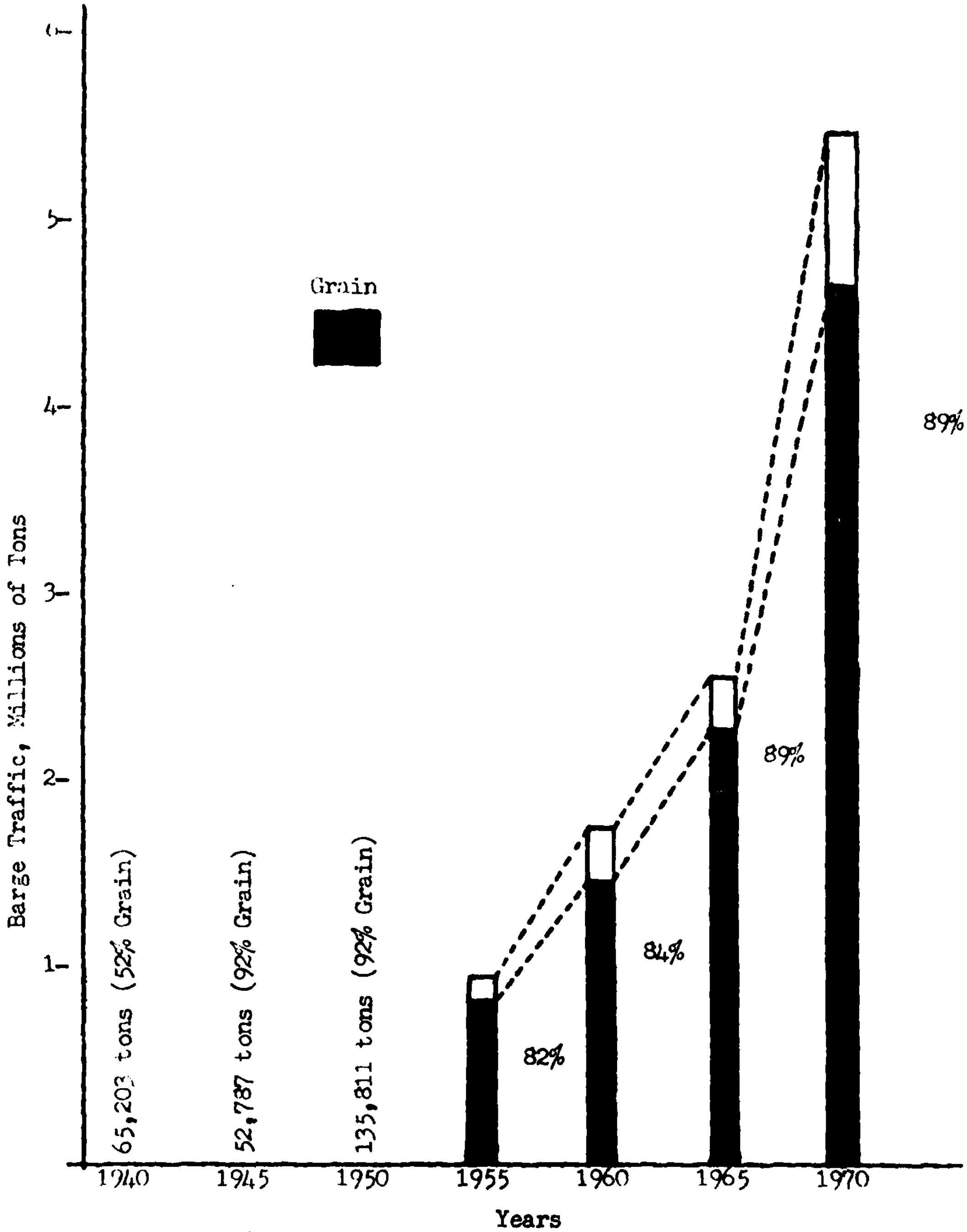

Figure 31 . Shipments Out of the St. Paul District. Data from U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota

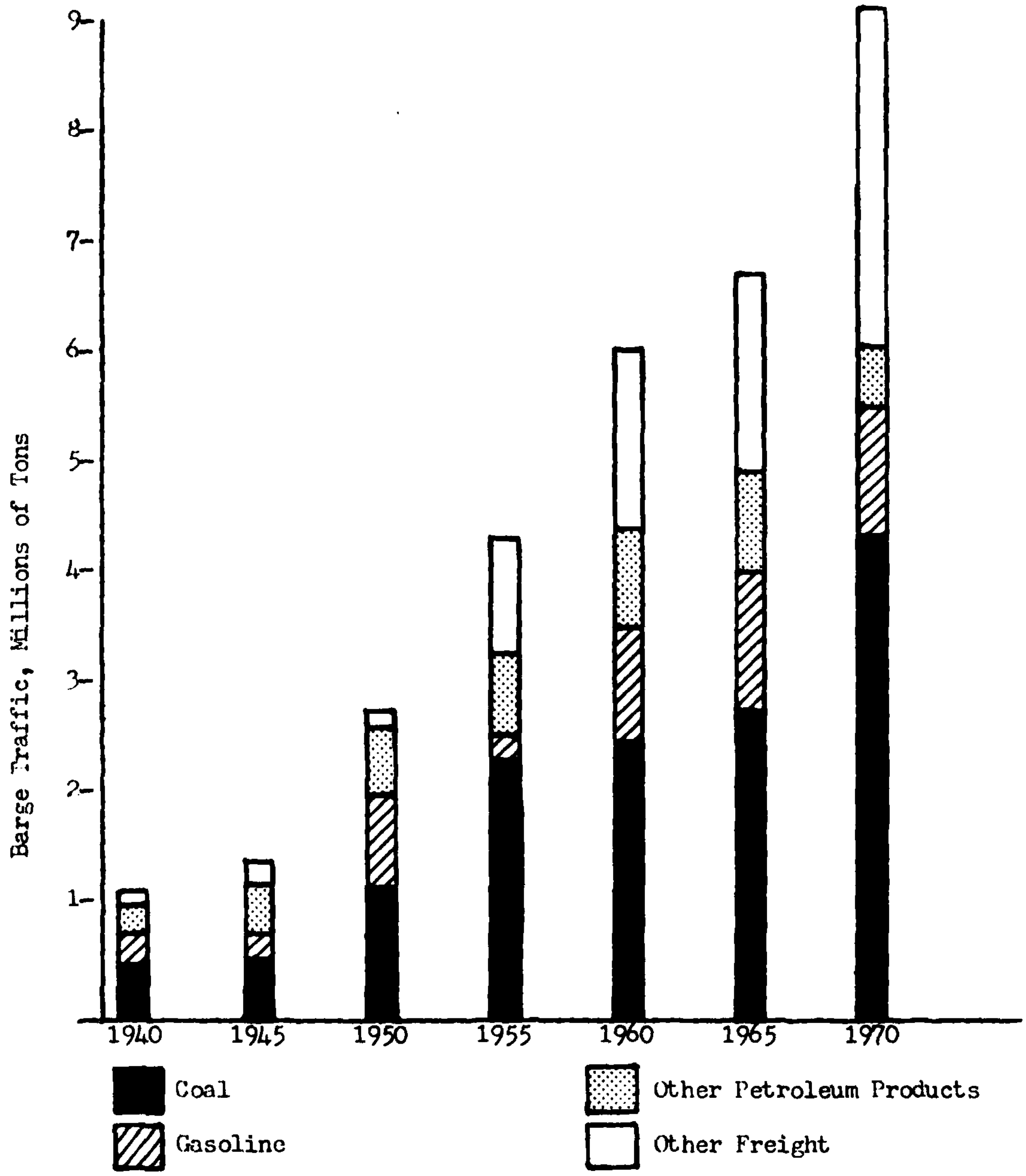

Figure 32. Receipts of Major Commodities — All Ports, St. Paul District. Data from U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota.

It is noteworthy that receipts into the St. Paul District have always exceeded shipments. In earlier years this imbalance was often extreme (e.g., 1953 receipts = 3,052,144 tons, shipments = 334,233 tons). Recently, however, the ratio has been around 2:1. Inasmuch as grains and soybeans constitute the preponderant tonnage of shipments, fluctuation in waterborne transport of these products can be profound due to crop conditions and storage facilities, foreign sales, and competing forms of transportation.

Data are not available on the numbers of vessels originating, terminating, or passing through the St. Paul District. However, some comparative idea of shipping activity can be gained from the following information. Vessel traffic measured in tons from Minneapolis to the mouth of the Missouri River is shown for selected years as follows:

Year	Total Vessel Traffic (Tons)
1962	30,526,626
1964	34,108,482
1966	41,311,941
1968	46,174,929
1970	54,022,749
1971	52,733,097

Certain industries, dependent upon barge traffic for their economic viability have located on industrial sites along the river. The investment which they represent and the employment they generate are also attributable to the activities of the Corps of Engineers. Connected with this physical evidence of the Corps impact is the human impact perhaps best expressed in the employment which these facilities and vessels provide.

Detailed data on the amounts of commodities originating in Pool 4 or destined for it are not available. However, analysis of commercial and industrial facilities adjacent to the pool suggests that the major commodities originating or terminating in the pool are grain, vegetable oils, and coal. Some comparative idea of barge activity can be gained from studying the commercial lockages through Lock 4 and Lock 3 — the locks at either end of Pool 4 — which are shown in Table 19. From 1960 to 1972 commercial lockages through Lock 4 increased by 47 percent and those through Lock 3 increased by 48 percent.

Table 19. Commercial Lockages in Pool 4
1960-1972

Year	Commercial Lockages Through ...	
	Lock 4	Lock 3
1960	1,313	1,303
1961	1,294	1,318
1962	1,313	1,302
1963	1,373	1,468
1964	1,410	1,463
1965	1,373	1,292
1966	1,519	1,568
1967	1,593	1,499
1968	1,485	1,558
1969	1,599	1,636
1970	1,862	1,576
1971	1,259	1,860
1972	1,913	1,931

Source: Annual Lockage Data, (St. Paul, U. S. Corps of Engineers, St. Paul District, Unpublished Reports).

Commercial Dock Facilities Firms that depend heavily on the river often maintain riverside facilities. Pool 4 contains five commercial docks and terminals, including two that serve the Central Soya Grain Company and Northern States Power.

Behind many of these docks are factories and storage facilities that are dependent upon them. Thus, the ramifications of river navigation reach deeply into the entire economy of the region surrounding Pool 4 and indeed throughout the whole upper Mississippi region. Employment directly and indirectly connected to these industries forms a small though significant percentage of the regional work force.

From an economic point of view most of the effect of the activities of the Corps of Engineers are beneficial. Ultimately the benefits of economic activity have to be measured in terms of providing livelihood to human beings. Employment generated by the availability of waterborne transport to Pool 4 includes both workers directly connected with the river itself and a far larger number of those whose livelihood is less directly dependent on water shipping. In the first category is included employment by the Corps of Engineers itself, workers on docks and shoreside facilities, and those working on the vessels themselves. The second category consists of those whose livelihood is gained by either utilizing the products brought into Pool 4 by waterborne carriers or who process goods shipped by water. Included in this category are those who supply goods and services to those directly involved with water shipping on the Upper Mississippi.

The total employment involved either directly or indirectly with all commercial operations on the river is not known. The Corps of Engineers itself has some 150 persons who are concerned with lock and dam operations. In addition to this the dredge "Thompson" has approximately 65 crew members. U. S. Department of Commerce data on employment on the Upper Mississippi are deficient as well. These data are collected for mid-March, a period when water traffic in the St. Paul District is almost completely inactive and seasonal lay-offs are in effect. Further, these data are aggregated in a way designed to prevent isolation and identification of particular firms. This also has the effect ofpreventing identification of employment or other economic activity in particular pools or even of particular waterways. However, some estimates of employment can be made. In mid-March of 1971 8,632 persons in the U. S. were employed in River and Canal Transport. This figure does not include warehousing or persons employed by firms where the SIC classification lies outside of transportation, even though they themselves may be working exclusively on the river. The same data show 556 persons in Minnesota as a whole who work in the field of water transport. This,however, includes the Great Lakes as well as the Upper Mississippi. Some of these people are employed by private dredging firms whose existence is dependent upon the work of the Corps.

A further benefit which can be attributed to the maintenance of navigation on the Upper Mississippi is in the savings in transportation costs, particularly for bulk commodities. Estimates of these savings

have been made. One of these estimates the savings over the other various least cost alternatives of between 4.0 and 5.4 mills per ton-mile. It is generally recognized that bulk commodities, particularly those having low value-to-weight ratios, are appropriate for barge transport. Coal, petroleum, and grain that have these characteristics are examples of such commodities that originate, terminate, and move through Pool 4 on River barges.

The socioeconomic impact of the physical effects of navigation cannot be measured precisely because of the inability to isolate single factors from a wide-range of potential ones. Dredging and the movement of tugs and barges does increase water turbidity to which must be added pollution from barge spillage, washing and loss while loading or unloading. Yet pollution is small relative to the load placed in the river from other sources. These impacts may have economic effects on commercial and sport fishing, which are discussed below.

Commercial Fishing Pool 4 is an important source of fish for commercial fishermen on the Northern Section of the Upper Mississippi River. Along with Pool 9 it is one of the two major sources of commercial fish in the Northern Section; during the 1960's these two pools ranked either first or second as the pool providing the greatest weight of commercial fish catch in the Northern Section of the Upper Mississippi River. The commercial catch in Pool 4 during the 1960's is shown in Table 20. The table shows wide variations in the annual commercial fish catch during the 1960's — reaching a maximum of about 2,600,000 pounds in 1964 and a minimum of about 1,500,000 pounds in 1969.

This increased commercial fishing in Pool 4 since the lock and dam construction is at least partially due to the beneficial impact of a larger area of fish habitat caused by the rising water level. However, in recent years improper dredge spoil placement and sedimentation below wing dams has reduced fish habitat. Some experts in river fishing believe that major year-to-year variations in commercial fish catches are less affected by the supply of fish in the river than by market demand, as reflected in prices commercial fishermen receive for their catch. For example, high meat prices in mid-1973 have caused fish prices to increase with an attendant increase in commercial fishing activity on the river (Fernholtz, personal communication).

Table 20. Pounds of Fish Caught Annually by Commercial Fishermen in Pool 4 of the Upper Mississippi River, 1960 to 1969. Source: Proceedings of the Annual Meeting of the Upper Mississippi River Conservation Commission, 1962-1971.

Year	Commercial Fish Catch
1960	1,629,000
1961	1,737,000
1962	1,836,000
1963	2,183,000
1964	2,593,000
1965	Not Available
1966	2,390,000
1967	2,240,000
1968	1,891,000
1969	1,498,000

Fur Trapping The expansion of improved fur beaver habitat became evident in a few short years following establishment of the slack water pools. Trapping was allowed starting in 1939 and has continued each year since then. Pool 4 has consistently been high in the number of pelts produced. Figures for the 1971-72 season show 11,117 muskrats harvested by 55 trappers. This is an indication that the habitat remains good enough yet to produce a healthy, harvestable surplus. Continual attrition however, by sedimentation and dredge spoil disposal will affect the productive capacity of the marshes so necessary to these animals.

In 1962-63 the last complete breakdown by pools available from the Upper Mississippi River Wildlife Refuge office showed the following information on fur taken in Pool 4: 38 trappers pelted 7,389 muskrats for a total value return to the trappers of $5,969. Other fur bearers are harvested, but in much smaller numbers, because of more restricted habitat. Muskrats enjoy the greatest expanse of suitable habitat in the marsh and shallow open water areas.

Recreational Impacts

Recreational impacts may be divided into boating activities and related facilities, sport fishing and hunting, and sightseeing and picnicking.

Boating Activities and Related Facilities For Pool 4 the best available measures of pleasure boating activity are records of pleasure boats locking through Locks 3 and 4 — the locks at each end of the pool. These data — along with the total pleasure-boat lockages through these two locks — are shown in Table 21 for the years 1960 to 1972. The table shows sharp increases in pleasure craft locking through both Lock 4 (from about 4,300 in 1960 to about 6,500 in 1972) and Lock 3 (from about 5,500 in 1960 to 8,100 in 1972) during the period. The table also shows an accompanying increase in the number of pleasure boat lockages during the period, although the increases have not been as dramatic as for the number of pleasure boats moving through the two locks.

Pool 4, containing Lake Pepin, represents the best boating in the entire St. Paul District and draws boaters from a wide area including the Twin Cities. Pool 4 is 44 miles long and has a water surface area of approximately 38,400 acres. A combination of size, location, relative water quality, facilities and accessibility makes it the prime water-oriented recreational resource in the northern part of the Upper Mississippi River.

Table 21 . Measures of Boating Activity in Pool 4, 1960-1972. Source: Annual Lockage Data, (St. Paul, U. S. Corps of Engineers, St. Paul District, Unpublished Reports).

	Pleasure Boats Through...		Pleasure Boat Lockages Through	
Year	Lock 4	Lock 3	Lock 4	Lock 3
1960	4,305	5,486	2,498	2,760
1961	4,361	5,490	2,400	2,748
1962	3,943	4,501	2,202	2,372
1963	4,225	5,113	2,472	2,497
1964	4,347	4,784	2,633	2,488
1965	3,621	4,139	2,108	2,096
1966	4,276	5,379	2,662	2,377
1967	4,179	4,519	2,519	2,528
1968	4,281	3,992	2,481	2,385
1969	4,523	3,747	2,485	2,499
1970	5,144	6,641	2,832	3,258
1971	6,086	8,051	3,613	3,282
1972	6,488	8,102	3,153	3,252

A variety of physical facilities have been developed in Pool 4 that exist mainly to serve boaters using the pool. These include:

Facility	Number
Small boat harbors, marinas, boat clubs	8
Recreational sites	8
Recreational sites with ramps	13
Commercial recreational sites	18
Wildlife refuges	2
Camps	1

Except possibly for the recreational sites without ramps, which do not cater primarily to boaters, and the one camp, all of these facilities result from Corps' operations on the River that contributed the channel and stable water levels.

The 9-foot channel and associated locks have provided stable water levels that have contributed significantly to the increased boating activity in Pool 4, along with increased regional population, higher levels of family income, and more leisure time. The increased pleasure boating has led directly to 23 public-use sites identified in Table 18 of Section 2.

Sport Fishing, Hunting, and Other Recreational Activities The size of the pool, the variety of access points and the lack of an adequate survey program have precluded obtaining an accurate count of Pool 4 visitation for past years. Neither the Wisconsin Department of Natural Resources (Fernholtz, personal communication) or the Minnesota Department of Natural Resources (Gulden and Sternberg, personal communications) nor the U. S. Bureau of Sport Fisheries and Wildlife (Chase, personal

communication) have recent, continuing data on sport fishing, sport hunting, and other recreational activity for Pool 4. The most precise data available are for 1963 and appear in Table 22. The data are a composite of both Corps of Engineers and Bureau of Sport Fisheries and Wildlife (from the Upper Mississippi River Wildlife and Fish Refuge) visitation compilations for that year. In addition to being the most accurate data available to date, they are the most usable since visitation survey estimates were broken down to show ratios of participation in the seven most appropriate activities on an annual and peak month basis. Total annual vistation to Pool 4 in 1963 was estimated at about 360,000 which represents the equivalent of about 3.6 visits for each of the 100,000 people residing in the zone of influence (St. Paul District, September, 1968).

Table 22. Pool 4 total visitation - 1963.

Activity	Annual 1963 Percent of Total	Annual 1963 Activity Participation	Peak Periods Percent of Total	Peak Periods Activity participation Month (July)	Peak Periods Activity participation Peak Day
Camping	6.1	21,960	7.8	6,710	510
Picnicking	8.8	31,680	10.5	9,030	680
Boating	30.6	110,160	35.2	30,270	2,290
Fishing	47.0	169,200	38.6	33,200	2,510
Water skiing	2.5	9,000	3.1	2,660	200
Swimming	4.0	14,400	4.8	4,130	310
Subtotal	99.0	356,400	100.0	86,000	6,500
Hunting	1.0	3,600		2,520(Oct)	190
Total annual	100.0	360,000			

Visitation during the peak month of July, 1963 was estimated at about 86,000 or 24 percent of the annual visitation. Table 22 shows a breakdown of total annual, peak month, and peak day visitation by activities. Visitation for hunting appears only under the annual category since it does not occur in the summer months and does not influence determination of summertime peak loads. It is estimated that about 75 percent of the total visitation shown in Table 22 is generated at or through available public-use sites. With the possible exceptions of camping and picnicking, the other five activities cited in Table 22, which account for over 85 percent of the total participation are water-related. It seems reasonable to conclude that the higher, stable water level in Pool 4 resulting from the construction of Lock and Dam 4 has had a favorable impact on these five activities.

The Winona District of the Upper Mississippi River Wildlife and Fish Refuge has collected public-use data on the portion of the refuge that lies in Pools 4, 5, 5A, and 6. These data appear in Table 23. These data emphasize the importance of the river as a recreational resource for fishermen, water-sport, and camping activities — over 80 percent of the visitors using the river for these purposes.

Table 23. Recreational Visits to Pools 4, 5, 5A, and 6. For 1971. (Winona District of the Upper Mississippi River Wildlife and Fish Refuge). Source: Narrative report for the year 1971. 1972 Winona, Minnesota Office of the Upper Mississippi River National Wildlife and Fish Refuge of the U.S. Department of the Interior.

Recreational Activity	Number of Visits in 1971	
Fishing		69,080
Hunting		
Ducks	18,910	
Deer	450	
Other	400	
Total		19,760
Misc.		
Water Sport - camping activities[a]	89,155	
Bird watching, wildlife observation wildlife photography	9,000	
Total		98,155
Total		186,995[b]

[a]Includes boating, sandbar picnicking, water skiing, swimming, and camping.

[b]Total does not include 8,290 trapping visits and 2,305 visits by Commercial Fishermen

Another source of data on sport fishing is available because attendants at each lock and dam make daily observations at 3:00 p.m. each day throughout the year of the number of sport fishermen observed from their work location. Annual data for the most recent years for which these records are available appear in Table 24. The table shows a wide variation in sport fishermen observed from Lock and Dam 4 since 1963. Because most sport fishermen observed from a lock and dam are downstream from the dam, most of the fishermen seen from Lock and Dam 4 are in Pool 5. Fishermen in Pool 4 — as seen from Lock and Dam 3 more than doubled from 1969 to 1970 — jumping from about 2,700 to 5,800 observed annually; no explanation is available for this increase. Also note that these data are only an index to sport fishing in the pool.

Table 24. Number of Sport Fishermen Observed Annually by attendants from Lock and Dam Sites at Both Ends of Pool 4 on the Upper Mississippi River, 1960 to 1970. Source: U.S. Corps of Engineers data published in the Proceedings of the Annual Meetings of the Upper Mississippi River Conservation Committee, 1962-1971.

Year	Lock and Dam 3	Lock and Dam 4
1960	2,627	8,178
1961	3,284	7,110
1962	2,733	6,863
1963	2,596	6,480
1964	2,830	7,076
1965	Not Available	Not Available
1966	Not Available	Not Available
1967	2,510	5,688
1968	3,013	6,194
1969	2,714	10,378
1970	5,752	7,030

Note: Counts are made once each day at 3:00 p.m.

In terms of impact on sport fishing, the higher water level in Pool 4 has increased the spawning areas for fish. In theory this offers the potential for more sport fishing. However, the potential both for increased commercial and sport fishing in Pool 4 may be partially offset by river pollution and turbidity from barge activity in it. Also in recent years dredge spoil placement has reduced the acreage of available fish habitat in Pool 4, and sedimentation has also hurt fish habitat — particularly in areas below wing dams. Therefore, Corps' operations following the construction of Lock and Dam 4 have had both positive and negative effects on fish (and also waterfowl) habitat in the pool.

As the water level in Pool 4 was raised by Corps' operations, habitat for residential and migratory waterbirds was initially increased. As with fish habitat, dredge spoil placement in recent years has also reduced waterfowl habitat. This suggests the potential for greater bird hunting adjacent to Pool 4. Some measure of hunting activity in the pool is shown in Table 22 that notes 3,600 hunting visits to Pool 4 in 1963.

Recreational sites along the perimeter of Pool 4 also facilitate sightseeing, picnicking, hiking, and camping. While non-boating visitors to these sites might be there whether Corps' operations existed on the Upper Mississippi or not, virtually all of the activities at these sites by boaters are attributable to Corps' activities. In addition, visitors to overlooks at locks and dams are a direct result of Corps' operations.

Cultural Impacts

Conversations with the State Archaeologists for Minnesota and Wisconsin (Streiff and Freeman, Personal communications) revealed no evidence to indicate any cultural impacts on sites in Pool 4 through the activities of the Corps of Engineers.

No archaeological sites are known to exist in the Pool 4 area. The two important historical sites, the Old Frontenac Historical District and Fort Beauharnais, have not been affected by Corps' operations.

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4. ADVERSE ENVIRONMENTAL EFFECTS WHICH COULD NOT BE AVOIDED AS THE PROJECT WAS IMPLEMENTED

NATURAL SYSTEMS

The primary adverse effect of the project is the obvious filling of the flood plain with sand and silt. Once-productive marshes have been transformed by dredge spoil into areas that resemble deserts. Less obvious is the filling of navigable channels with sand. Even young men are able to cite many instances of losses of navigable waters which have occurred in their life times.

Barrier islands of dredge spoil have interrupted flow patterns in sloughs, marshes and lakes. The consequent loss of oxygenated water at the bottom of flood plain lakes has caused a decrease in the production of invertebrate animals. Organic material which settles to the oxygen-deficient bottom of such areas does not decompose readily, hence it accumulates rapidly and further decreases the volume of the body of water.

Reservoir filling is a deviation-accelerating mechanism, wherein the rate of filling may be imperceptible during the early years of impoundment. Subsequent sand deposition, however, speeds the accretion of additional sand. Emergent aquatic vegetation and pioneer tree species colonize the sand deposits and slow the velocity of the river during flood time. The competency of the river is thus decreased and new sand deposits are formed when the slowed river drops its load of sand.

Sand accumulations stagnate backwater areas so that the build up of organic material proceeds more rapidly. The rate of loss of aquatic habitats is now proceeding so rapidly that it is apparent even to casual observers.

It has been known for many years that reservoirs predictably fill in with sand and silt. It is unfortunate that preventive maintenance procedures were not initiated as soon as the 9-foot project was a reality. It is doubtful if the very serious sand accumulation problems associated with the project can truly be termed unavoidable. The writers of this report feel that they could have been at least moderated.

Other unavoidable adverse effects include the destruction of clam beds by siltation, and the killing of flood plain forests by covering them with dredge spoil.

Wing dams and closing dams are definite hazards to pleasure boats.

The present system of locking pleasure boats is often extremely slow and it is aggravating to most pleasure boaters. Navigation interests are given priority in all instances, at the expense of the general public.

Increased barge traffic has increased the likelihood of spills of oil and other chemicals.

The inundation of submarginal farm land by the navigation pools has been said to be detrimental because it removed land from the tax rolls.

5. ALTERNATIVES

The impacts on the environment caused by construction operations and maintenance of the 9-foot project have been identified and their significance measured. There are, then, alternatives to consider to correct, minimize or eliminate the objectionable features of the project.

In discussing alternatives, one should make distinctions on the basis of correcting deficiencies. This could mean changes in the entire method of operations and maintenance, elimination of the project, or variations somewhere in between.

Thus, the first alternative to consider, outlandish as it may seem, is to eliminate the project, return the river to its state prior to 1930, and in so doing cause more and greater consternation than now exists with the project.

Even with elimination, there would still be a major problem in the river, that being the ever-present sediment load. Of all objections to the project, sediment and its disposal cause the greatest concern among economists, environmentalists and the Corps of Engineers.

The first alternative to be considered in channel maintenance is how to best manage the sedimentation problem. The Corps at present is using methods that have changed but very little since navigation began on the river - the removal of sand or sediment deposits from the navigation channel and placing them at the closest spot for the lowest

possible cost. New methods of disposal have not been considered too strongly until quite recently, when concerned citizens questioned the huge amounts of spoil being piled up along each side of the river channel.

Several alternatives to the present methods of handling the spoil problem are listed below.

CHANNEL MAINTENANCE

Holding Sediment in Place at its Source

The Corps of Engineers has consistently maintained that the sources of most sediment in the river are beyond its jurisdiction - coming from tributaries of the main stem, and that local, state and possibly other Federal agencies should apply themselves to erosion prevention practices that would reduce the sediment load. The alternative here is to have the Corps take immediate steps to foster actions to determine problem areas and apply pressure to correct the fault and thus reduce to a minimum the sediment entering the river.

Removal of Spoil from the Flood Plain

Little has been done by the Corps to encourage beneficial uses of dredge spoil outside the flood plain. A first order of business should be an analysis of the material to determine its suitability for commercial uses such as concrete aggregate, highway sanding, landfill operations or other applications.

According to an Upper Mississippi River dredge spoil survey conducted by the Minneapolis Region III Office of the Bureau of Sport Fisheries and

Wildlife (March 29, 1973), dredge spoil could be a useful resource rather than a detimental burden to the river environment. The survey contacted 21 city governments, 24 sand and gravel companies and one county conservation board. The data indicate that there may be a large market for spoil material for a wide variety of uses among the 600 cities and villages which be within 20 miles of the river between Cairo and Minneapolis. The report states that the potential market for spoil between Cairo and Minneapolis may be as much as 16,000,000 cubic yards, with an estimated 25.7 million dollars.

In order to ascertain the possible demand for dredge spoil in the Pool 4 - Pool 6 area, a meeting was held in Winona on July 31, 1973 with area highway engineers. In attendance were Earl Welshons, Winona County Highway Engineer; Jerry L. Spencer, Area Maintenance Engineers (Minnesota State Highway Department); Gary Latterell, District Materials Engineer (Minnesota State Highway Department) and Richard C. Brown, Wabasha County Highway Engineer. Dennis Nielsen, Winona State College geologist, presented a series of spoil samples from Pool 4, 5, 5A and 6 to the group for examination. Their consensus was that the sand was clean and sharp and that it was suitable for almost all construction uses. Upon his return to Rochester, Mn.,Latterell appraised a random series of dredge spoil samples and submitted the following report in his letter of August 15, 1973:

> "At your request, we examined the gradation test results you submitted. The gradation, of these Mississippi River sand samples, do not vary too much from Pool 4 to Pool No. 6.

According to Minnesota Highway Department Specifications the river sand could be used as a (3126) Concrete Sand, a (3128) Mortar Sand, a (3127) FA-1 Bituminous Seal Coat Aggregate, and a (3128) Class 3 or Class 4 Aggregate Base material if a little binder soil was added. This sand would also make an excellent embankment material if some binder soild were added. It could be used in winter sanding operations, and also used as an additive to crushed limestone in the production of (3139) Bituminous Aggregates."

Unfortunately, the engineers in attendance at the meeting estimated that total usage of sand by Winona County, Wabasha County and the State of Minnesota in the two county area would not exceed 100,000 cubic yards per year.

Establishment of a Permanent Dredging Installation at the Mouth of the Chippewa River

The geological sections of this report make it obvious that the Chippewa River is the major source of sand in the entire St. Paul District. Moreover, the sand brought into the Mississippi by the Chippewa is of excellent quality. A permanent dredging installation could be established at the mouth of the Chippewa to intercept sand which continually washes into the Mississippi. The sand could be stockpiled on a portion of the adjacent bottomland controlled by the Bureau of Sport Fisheries and Wildlife, where access by road and railroad could be gained for hauling the spoil away. Spoil could also be contained near the dredging site to create a recreational area suitable for camping and boating.

Intercepting sand at the mouth of the Chippewa would mitigate the constant redredging of sand which washes back into the river from

previously made spoil piles.

Equipment

Some of the problem of spoil disposal could be solved by procurement of equipment that would move spoil farther, faster, higher, in greater volume and in a more versatile fashion. Moving spoil greater distances would enable uses of spoil, off channel, to benefit wildlife and recreational facilities. It would also be used to make the materials available for commercial uses as discussed above.

In Pools 4 and 5 there are large shallow open water areas subject to wind and wave action to the detriment of valuable plant associations used by fish and wildlife. Dredge spoil, if it could be pumped a mile or more, could be used to form barrier islands that would reduce wave action, thus favoring the plant life by reducing turbidity and mechanical damage by wave action.

Stabilization and Containment of Dredge Spoil

The results of the present study have made it apparent that dredge spoil does not stay in position after it has been dredged from the river. Much of it is washed into the main channel and backwaters by wave action, floods and rain. Less obvious is wind action which moves fine sand back into the river. The coarse, pebbled appearance of old spoil piles illustrates that fine sand has blown away, leaving coarser, heavier particles behind.

If the bare sand surfaces of spoil piles could be vegetated, sand losses to the river could be minimized. Moreover, vegetated sand would be more productive of wildlife than bare sand. Vegetated sand could be

piled higher with steeper sides than non-vegetated sand. Many bare piles now exhibit only a 5% slope, thus necessitating broad bases for the piles The broad bases, in turn, inundate large areas of once-productive marsh habitat.

If grassland could be established on sand surfaces above normal flood levels it may even be possible to increase the numbers of local nesting waterfowl. At the present time, local nesting ducks are forced to nest along the water's edge because suitable cover is not found higher on spoil piles. Floods in late spring or early summer usually destroy such nests.

A meeting was held on August 9, 1973 with Dr. Lawrence E. Foote (Director, Environmental Services, Minnesota State Highway Department) and Leo J. Holm (Agricultural Engineer, Minnesota State Highway Department). The purpose of the meeting was to determine if it would be possible to stabilize sand dredge spoil desposits with vegetative cover in the manner that state road cuts are stabilized.

The party visited and inspected in detail certain vegetated road cuts along Highway 61 south of Winona and spoil deposits in Pool 5 near West Newton and in the Lost Island area near Buffalo City.

Sand movement by wind erosion was apparent at all sites. The observers estimated that two or more feet of fine sand had been blown from many older sites. The sand loss was made apparent by the density of larger pebbles on the surface of older sites.

The opinions of Dr. Foote and Mr. Holm were that the sand would be relatively easy to vegetate and that fertilizer was the principal limiting factor to plant growth. They felt that many old spoil sites which contained a relatively dense growth of spindly, impoverished weeds could be effectively treated with fertilizer to stimulate plant growth. After fertilizer elements are once incorporated into plants, a natural nutrient cycle would be established, especially if legumes are utilized as nitrogen fixers. Subsequent fertilization at several-year intervals may be necessary in most areas. They also felt that the growth of small trees could be stimulated by fertilization. Willows could be propagated by cutting wands and by planting them with a mechanical tree planter.

In bare sand areas they recommended the application of a mixture of mulch, fertilizer and seed. The rate of fertilizer application would be determined by soil test. They recommended the following mixture which would be planted with a Hydro-Seeder.

field brom grass	-	8 lb./acre
sand drop seed	-	3 lb./acre
sand love grass	-	3 lb./acre
hairy vetch	-	15 lb./acre
switch grass	-	3 lb./acre

The seed and fertilizer would be applied in the fall, followed by a second fertilizer application 1½ years later. In addition to making plants grow faster, the fertilizer will cause them to produce better, larger seed, thus increasing the chance of success of the seedlings which

sprout from the seed.

Seed planting must be accompanied by using techniques to break the force of the wind (mulch, snow fence, willow wands, etc.). Timing of seeding is very important and great care must be taken to prevent the seed from being blown away.

The best species of grass for the area is probably American beach grass. The grass cannot be readily established from seed, however, and clones of the grass must be planted by hand or with a mechanical planter. The clones would be planted about four feet apart and new plants would develop naturally because the species is characterized by vigorous rhizome development. American beach grass is available from the U.S. Soil Conservation Service. Crops such as perennial wheat could be established to provide food for wildlife.

The observers' general impression was that the Corps needed an overall plan for the management of dredge spoil. Some areas should be left as sandy beaches. Sandy areas which are not used as beaches should be stabilized with prairie-type vegetation which would also increase the carrying capacity of the area for wildlife.

Vegetation of spoil piles may be the most easily implemented, lowest cost, most beneficial program that can be implemented. Pilot projects and research programs should be initiated as soon as possible.

There is need in many cases for containment structures of any of several types--gabions, piling, dikes, etc. The concern of the Corps as

to the cost of this procedure could be overcome by continuing surveillance to determine the volumes lost from disposal sites back into the river.

Continuing Dredge Spoil Survey

Only two dredge spoil disposal surveys have been made on the river and these have been made within the last 15 years. Each of the two surveys was made by parties consisting of Corps representatives and natural resource managers from federal and state agencies, with the principle in mind of reducing environmental damage to the habitat by recommending the locations where dredge spoil could be placed.

The Corps should immediately organize a team of professionals from the same disciplines of previous surveys. The team should program disposal activity annually. Such routine activity could eliminate many problems by increasing the awareness of all parties concerning space available for placement of spoil, needs of users outside the flood plain, and beneficial uses of varying amounts within the flood plain.

Dredging Needs

Little is known outside the Corps of the factors which influence maintenance dredging procedures. Information on frequency of dredging needed, dredging beyond minimum depth and channel width and others affecting the annual amount of sediment to be dredged should be available.

There is distrust in some quarters that some of the current dredging

is covertly reaching toward a 12-foot channel depth, though this is denied by the Corps. There is need, however, for assurances to cooperating agencies concerned with the effects of dredge spoil on fish and wildlife, recreation and the general environment that the dredging done each year be only that which will maintain the facilities for the purposes authorized by Congress.

Coordination

There is need for closer coordination between the Corps and relevant cooperating Federal and State agencies such as the Bureau of Sport Fisheries and Wildlife, the Minnesota Department of Natural Resources and the Wisconsin Department of Natural Resources. Although contact is generally maintained between the Corps and these agencies there are frequent breakdowns in communications on delayed or interrupted dredging schedules, resulting in dredging in areas of critical concern to one or more agencies.

There is also a need for a professional biologist to be stationed with the dredge so that discussions on a technical plane can take place. It is difficult at times to reach understandings between biologists and engineers or dredge operation supervisors as to environmental problems involved in particular instances.

Other Sedimentation Studies

In addition to dredge spoil surveys, there is great need for establishment of sedimentation ranges to measure sediment increment rates, flow characteristics and vegetative changes which would be difficult to define without regular measurement.

DAM OPERATIONS

Operation of the dams is a highly technical procedure involving inflows from the entire basin and the maintenance of authorized water levels. Lands for the project were purchased to a minimum contour allowing some freeboard for operations. Some flowage easements were also acquired where temporary overflow could take place.

Within these confines, therefore, rather strict regulation must take place so that waters do not overflow on to private lands. Thus, regulation often works to the detriment of fishermen, hunters and other recreationists. There have been many instances when hunting and fishing areas have been converted into mud flats by manipulation of dam gates.

Recreationists on the river feel that their interests should receive consideration in the manipulation of water levels during any given period, and they are usually more concerned about low water conditions than they are about high water conditions.

The alternative here is to look into the operations of the dams to benefit recreational uses as much as feasible. After all, it was demonstrated that the so-called "anti-drawdown" legislation was a result of action by river users other than navigation interests.

Money has been available, at various times in Corps programs, for the purchase of critical areas for recreational enhancement of the project. The areas could have included lands where manipulation of pool levels

could have provided alleviation of deterioration of recreational values. Little, if any,money was spent for this purpose although several lists of desirable tracts were prepared and submitted to theCorps by Upper Mississippi River Wildlife Refuge personnel.

LOCK OPERATION

Recreational boat traffic is reaching such great proportions that special consideration must be given to facilitate their movement from one pool to another. Completion of construction of the auxiliary locks at Dames 4, 5, 5A, and 6 should be programmed for the near future in the interests of time and safety for recreational boaters.

Until such time as these auxilaries can be completed, a closer look at passage of recreational craft should be taken toward their owners' rights as users and supporters, with tax dollars, of these facilities.

6. SHORT TERM USES VERSUS LONG-TERM PRODUCTIVITY

INTRODUCTION

The establishment of the project has provided many short-term benefits to date. Although project lands were removed from tax rolls, and flood plain farming and timber harvesting were abandoned, the resulting water complex has provided the public with a recreation area that could not have been accomplished in any other way. The area has provided boating, fishing, camping, swimming, hunting, water skiing, picnicking and sight seeing for millions of people.

The inundation provided greatly increased habitat for many species of fish and wildlife. The marshes and lakes have hosted millions of birds on twice-yearly migrations, permitting the public great opportunities to enjoy them by viewing or hunting.

Unfortunately, however, the long term outlook is bleak. Continuing sedimentation is raising the flood plain, filling lakes and marshes and obstructing boat travel in the backwaters. Ultimately, the 9-foot navigation channel and a few major chutes may be the only water to survive.

The public has enjoyed the incidental, unplanned, "goods" associated with the 9-foot channel for about 40 years. The long-term "bads" are now becoming increasingly apparent. Even casual observers are aware that the pools are filling in. They are also aware that increased navigation traffic has caused the inevitable increase of barge

terminals, oil tank farms, fleeting areas, and industrial development. These activities require off-channel dredging, harbor dredging, and fill operations - all of which detract from the natural environment.

GEOLOGICAL IMPACT OF THE 9-FOOT CHANNEL

The construction of many locks and dams on the Upper Mississippi River has created many hydrologic and sedimentologic changes. The purpose of a dam is to provide storage of flow during periods of high water, for use during periods of low flow. When discharges are sufficient to maintain a normal or higher pool level at the dam, open river conditions prevail and the gates are in the raised position. With this condition of water-surface slope is generally parallel to the stream bed and the dams are, for all practical purposes, not hydrologically important. As the discharge decreases, the gates are closed to maintain a minimum pool level at the dam. Water piles up behind the dam forming a pool which has a surface extending upstream to a point where it intersects the normal pre-impoundment gradient of the river. Above the intersection point, the river is relatively normal and is unaffected by the dam downstream from it.

Velocity and Sedimentation

An obvious consequence of the lock and dam construction is the change in stream velocity within each pool. Velocities are reduced behind each dam because of the backwater effect of the gates. Because of the velocity decrease, aggradation is initiated behind the dam. The point of deposition moves progressively upstream as the discharge continues to

decrease and the amount of gate closure is increased. While sediment is being deposited in the lower reach of each pool, movement of sediment continues in the upper reach above the pool level. During controlled river flows, essentially a degrading and aggrading stream exists between dams. When the discharge increases and the gates are opened sediment will be eroded near the dam. The amount of sediment removal would depend on the magnitude and duration of flow.

Velocity measurements were made in the main channel of Pools 4, and 5 on June 12, 1973. A Price current meter was used to make measurements at various surface-midstream positions within each pool. Figure 3/ shows a plot of current velocity, river mileage and also the amount of sediment dredged by the Corps of Engineers in the same stretch of the Mississippi River. A near doubling in velocity of the Mississippi occurs at the junction with the Chippewa River. The Mississippi River maintains the same velocity as the Chippewa for a disance of about 2 miles downstream from the mouth of Chippewa River. Within that short distance the Mississippi has the competence and capacity to transport most of the bed load supplied by the Chippewa as indicated by the small amount of dredging between river miles 760 and 762. Downstream from Wabasha, Minnesota (mile 760), the Mississippi widens and the velocity drops to the point where it cannot transport the coarse bed-load sediment. As a result, the Corps of Engineers must dredge thousands of cubic yards of bed load each year to maintain the 9-foot channel. Before the building of wing dams and locks and dams, that stretch of the Mississippi was primarily braided into many smaller channels that individually had velocities great enough to transport the

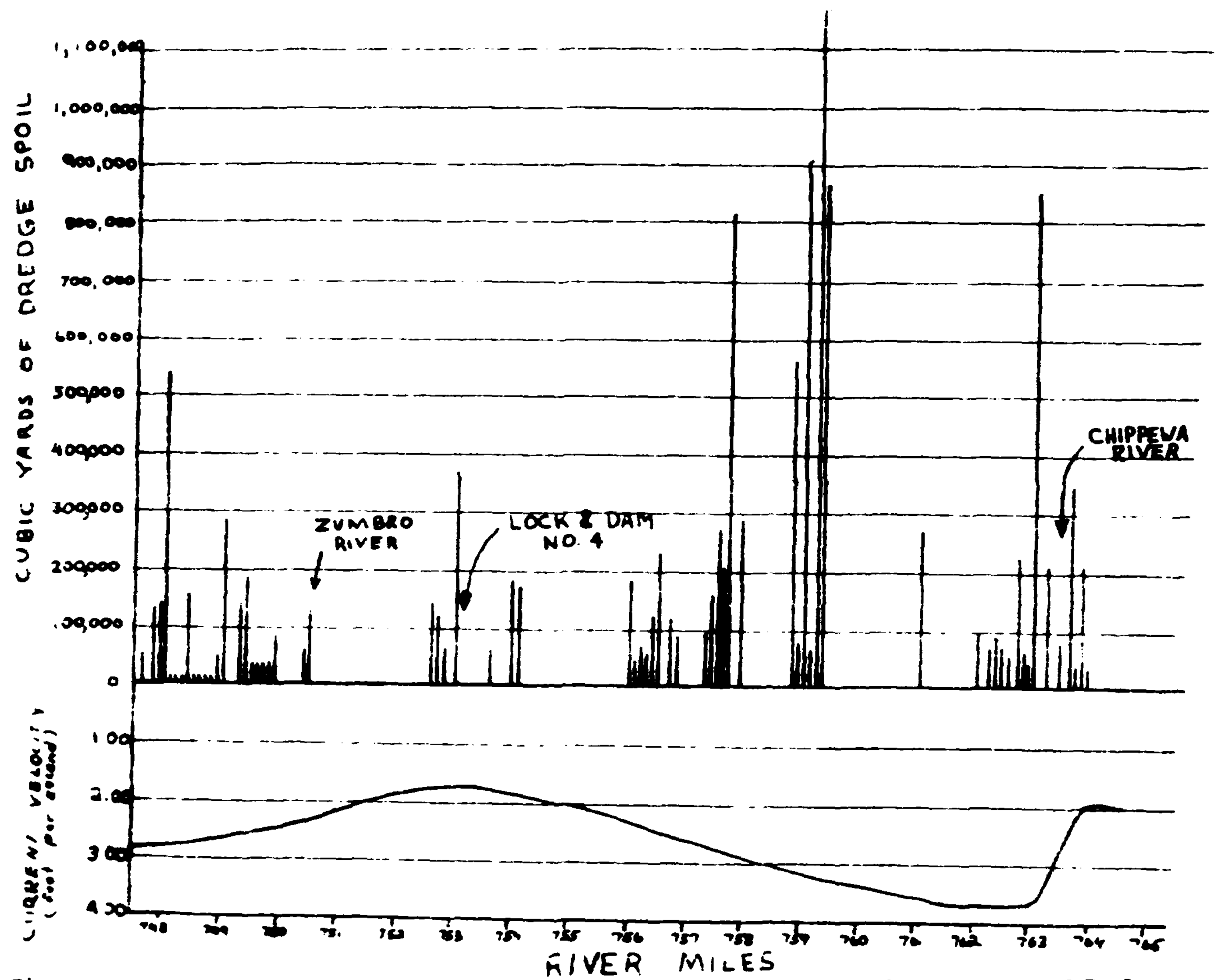

Figure 31 -A graph showing current velocity and cubic yards of spoil dredged from parts of Pools 4 and 5.

coarse bed load. A steady decrease in water velocity is found with increasing distance below each dam and consequently the dredging problems increase downstream from each dam.

The contruction of locks and dams has also affected many tributary streams of the Mississippi. Many tributaries that prior to dam construction flowed directly into the main channel of the Mississippi now flow into backwater portions of the many pools. The pools have increased the local base levels of these streams and as a result the streams aggrade farther upstream than they previously did. Much of the tributary sediment does not reach the main channel because it is deposited in a quiet backwater area. The Whitewater River is a good example of such a situation. The Whitewater River flows into the Weaver Bottoms where there is limited circulation. Thus most of the Whitewater stream load never reaches the main channel.

It is very doubtful that occasional floods clean out all the annual sediment deposited in the backwaters of the Mississippi. Such floods would have to be very large and of long duration to do so. Significant evidence exists, such as that cited throughout this report, that flood plain aggradation is occurring in most pools in the Mississippi. Unfortunately, no quantitative studies have yet been made of flood-plain-sedimentation rates. If the bottom elevation of the pools is increasing, then this would certainly affect the stage of flooding because the difference between the bottom elevations and the height of flood dikes would decrease with time.

In a recent paper (1970) by A. R. Robinson, director of the U. S. D. A. Sedimentation Laboratory at Oxford, Mississippi, sediment was described as our greatest pollutant. He states that sediment has a two-fold effect: it depletes the land resource from which it is derived, and it impairs the quality of the water resource in which it is entrained and deposited. President Nixon noted the seriousness of water pollution from the land in his message on the environment during February 1970 when he stated:

> "Water pollution has three principal cources: municipal, industrial, and agricultural wastes. Of these three, the most troublesome to control are those from agricultural sources: animal wastes, <u>eroded soil</u>, fertilizers and pesticides."

Former Secretary of Agriculture Clifford N. Hardin, stated in a speech before the National Farm Institute:

> "Siltation is still the largest single pollutant of water. Our responsibility is to manage the environment for the widest range of beneficial uses, without degrading it, without risk to health or safety, and without loss of future productivity."

J. B. Stall (1966) determined the economic liability and monetary loss due to sediment pollution. The total annual damage from sediment in streams, not including loss of agricultural productivity of farm land lost to erosion, was estimated to be 262 million dollars in 1966. This amount was broken down by Stall as follows: deposition on flood plains, 50 million dollars; storage space destroyed in reservoirs, 50 million dollars; dredging sediment from inland navigation channels and harbors, 83 million dollars; removal of excess turbidity from public water supplies, 14 million dollars; removal of sediments from drainage ditches and irrigation canals, 34 million dollars; other damages including sediment removal,

cleaning, and added maintenance, 31 million dollars. These dollar figures are for the entire United States but nonetheless the Upper Mississippi River Basin costs can be estimated. The Upper Mississippi River contributes about 25 million tons of sediment out of the 4 billion tons carried from all rivers in the United States each year (Mack, 1970). This amounts to roughly 1 percent of the total. The minimum cost of sediment pollution is 2.62 million dollars for the Upper Mississipi based on 1 percent of 262 million dollars (1966 data). This cost is undoubtedly low because of the high channel-maintenance costs of the Upper Mississippi.

Recently, increased attention has been given to the role of sediment as a carrier of plant nutrients, pesticides and toxic elements such lead, mercury, cadmium, nickel and arsenic (Robinson, 1970). Plant nutrients such as nitrogen, phosphorous, potassium and certain trace elements are sorbed on sediments and may have biological significance in the eutrophication of ponds, reservoirs and lakes. Research indicates that clay minerals such as those found in river sediment, have active surfaces that react with an array of chemicals including some radioactive isotopes released from nuclear-power plants. These compounds may be concentrated in the sediment over a period of years and then released during a high-flow period. Little information is available on this aspect of sedimentation.

Dredging

There are several geologic changes that can attributed to channel dredging in the Upper Mississippi River. Spoil piles of sand and gravel

increase in areal extent each year because of channel dredging. As a result, the spoil piles are enlarged to the point where they can restrict and in cases block backwater circulation of water. If backwater circulation is impaired, the water velocity is decreased resulting in increased sedimentation in backwater parts of the flood plain.

The water-storage capacity of the backwaters is reduced because of channel dredging. Dredge spoil is in many cases dumped into the backwaters adjacent to the main channel of the Mississippi. The spoil is coarser than the backwater mud and thus forms a protective armor over the mud. The weak backwater currents generally have an insufficient velocity to remove the spoil, consequently, the spoil remains as a permanent deposit within the flood plain. As time continues, more and more spoil is dumped into the backwaters reducing the water volume and increasing the sediment volume. The backwaters of the flood plain serve as a safety valve during floods, relieving the main channel of excess water. When the storage capacity is reduced, the flood crests increase.

RESOURCE IMPLICATIONS FOR SOCIOECONOMIC ACTIVITIES

Table 25 summarizes the major resource implications of continuing to operate and maintain the 9-foot channel in the St. Paul District. Resource implications for these four groups are discussed in sequence below.

Corps' Operations

Table 25 identified the major first order direct benefits associated with lock and dam operation and dredging operations. These include employment in lock and dam and dredging operations, maintenance of relatively stable water levels in each pool, and the presence of a navigable 9-foot channel in the St. Paul District. About 150 people are involved with lock and dam operations in the district and about 75 with dredging operations; thus about 225 people derive jobs and income directly from Corps' operations. The annual direct cost to taxpayers for lock and dam operations is $2,601,000 (FY 1970) and for dredging operations is $1,200,000. Specific environmental costs of the stable water levels in the pools and the 9-foot channel in the St. Paul District are an increase in sedimentation behind dams and wing dams and a reduction in fish and waterfowl habitat due to sedimentation and dredge spoil placement.

Table 25. First-Order Benefits and Costs to Socioeconomic Activities of Maintaining the Nine-Foot Channel

Socioeconomic Activity		Qualitative Summary of Socioeconomic Benefits and Costs	
General Category	Specific Activity	First-Order Socioeconomic Benefits	First-Order Socioeconomic Costs
Corps' Operations	Lock and dam (L/d) operations	1. L/D employment. 2. Stable water levels.	1. Cost of L/D operation. 2. Sedimentation behind dams and wing dams.
	Dredging Operations	1. Dredging employment. 2. 9-foot channel	1. Cost of dredging operations 2. Destruction of fish and wildlife habitat due to improper dredge spoil placement.
Industrial	Barge Operation	1. Barge Employment 2. Low-cost water transportation. 3. Energy saving compared to alternate transportation modes.	1. Increased river turbidity. 2. River pollution from oil and gasoline from barges
	Commercial Dock	1. Dock employment. 2. Attraction of barge transportation oriented firms that provide local employment.	1. Increased river pollution from industrial activities along shore.
	Commercial Fishing and Trapping	1. Increased employment of fishermen and trappers 2. Increased number of fish and pelts available for consumers.	
Recreational	Boating Activity	1. Increased recreational opportunities for boaters.	1. Increased litter problems.
	Operation of Recreational Facilities	1. Increased employment and business opportunities for facilities serving recreational users of the river (boaters, sport fishermen and hunters, etc.)	

Table 25. First-Order Benefits and Costs to Socioeconomic Activities of Maintaining the Nine-Foot Channel (Continued)

Socioeconomic Activity		Qualitative Summary of Socioeconomic Benefits and Costs	
General Category	Specific Activity	First-Order Socioeconomic Benefits	First-Order Socioeconomic Costs
Recreational (Cont.)	Sport Fishing	1. Initially increased habitat for fish	1. Increased sedimentation in fish habitat. 2. Decreased fish habitat from improper dredge spoil placement.
	Sport Hunting	1. Initially increase habitat for waterfowl.	1. Decreased waterfowl habitat from sedimentation and dredge spoil placement.
	Sightseeing, camping, picnicking, swimming, water skiing	1. Improved opportunities for miscellaneous recreational activities.	1. Increased litter problems.
Cultural	Archaeological Sites		1. Loss of selected sites due to L/D construction and rising water
	Historical Sites		1. Loss of selected sites due to L/D construction and rising water.
	Contemporary Sites		1. Loss of selected sites due to L/D construction and rising water.

Industrial Activities

As summarized in Table 25 the major direct impacts at Corps' operations on industrial activities are for barge operations, commercial dock operations, and commercial fishing. Table notes that there are employment implications for each of these three activities but these benefits must be balanced against accompanying increases in sedimentation turbidity, and possibly other pollution in the river.

Of special importance in the current energy crisis are the answers to two questions that relate to barge transportation: How effective is barge transportation relative to other modes of transportation with respect to:

1. Energy usage?
2. Air pollution?

Because the answers have major resource allocation implications for the Upper Mississippi River, these two questions are analyzed below in some detail. In addition savings in transportation costs due to barge movements are discussed.

Barge Transportation and Energy Usage

Effective energy utilization is particularly important due to the present (and probably continuing) energy crisis. It also affect air pollution which relates directly to transportation energy consumption.

At present transportation utilizes about 25 percent of the total

U.S. energy budget for motive power alone. This usage has been increasing at an average annual rate of about 4 percent per year.

In comparing the efficiency of energy utilization between various transportation modes the term "energy intensiveness" is commonly used. Energy intensiveness is defined as the amount of energy (in BTU's) needed to deliver one ton-mile of freight. The following table compares the energy intensiveness of various modes of freight transportation (Mooz, 1973):

Freight Mode	Energy Intensiveness (BTU's/ton-mile)	Ratios of E.I.
Waterways	500	1
Rail	750	1.5
Pipeline	1,850	3.7
Truck	2,400	4.8
Air Cargo	63,000	126

It is apparent from this table that motive energy is utilized more efficiently in water transportation than through any other mode of freight transportation. Therefore, under conditions of restricted petroleum energy availability the use of barging wherever feasible should be encouraged. Indeed, an increased use of the Upper Mississippi and its tributaries is likely. Influencing this will be increased shipments of grain out of the St. Paul District and increased imports of coal and petroleum products into the region. Exports of grain to other countries and shipments of other parts of the U.S. are expected to increase. Energy demands in the Upper Midwest are also expected to rise. In addition

freight which is now only marginally involved in barging may shift from other forms of transportation to the less energy-intensive forms. This shift may also be expected to change existing concepts of the kinds of freight suitable for barging with consequent impact on storage facilities. In many cases economic trade-off may exist between the mode of transportation and the size of inventories considered to be suitable. If the energy costs rise sufficiently, increased capital necessitated by use of the slower-moving barge transportation and tied up in inventory and in storage space may be justified. If this occurs, other kinds of cargoes presently shipped by rail or truck or pipeline may be diverted to barge.

In addition to energy conservation, the importance of the Upper Mississippi as a transportation artery is shown by the burden which would be placed on the rail system (as the major alternative transportation mode used to move heavy, high-bulk commodities) in the absence of barge traffic on the river. In 1972 an estimated 16,361, 174 tons of various commodities were received and shipped from the St. Paul District. Under the simplifying assumption that the average box or hopper car carried 50 tons, this amounts to the equivalent of 327,223 railroad cars or some 3,272 trains of 100 cars each or approximately nine trains each day of the year.

Barge Transportation and Air Pollution

Barge transportation also results in less air pollution per ton-mile than either rail or truck modes. Diesel engines are the most common power plants used by both towboats and railroads. A large percentage of

over-the-highway trucks use diesel engines as well. The diesel engine is slightly more efficient than the gasoline engine due to its higher compression ratio. Thus, less energy is used to move one ton of freight over one mile by diesel than by gasoline engines. Among users of diesel engines, barging is more efficient than either rail or truck, as we have seen. Consequently, a smaller amount of fuel is required to move freight. With less fuel used, air pollution is reduced.

The amount of air pollution caused by either diesel fuel or gasoline varies substantially only in the type of air pollution. The following table illustrates these pollution effects (U.S.P.H.S., 1968):

	Emission Factor	
Type of Emission	Pounds/1,000 gallons diesel fuel	Pounds/1,000 gallons gasoline
Aldehydes (HCHO)	10	4
Carbon monoxide	60	2300
Hydrocarbons (0)	136	200
Oxides of Nitrogen (NO_2)	222	113
Oxides of Sulfur (SO_2)	40	9
Organic Acids (acetic)	31	4
Particulates	110	12

Based upon the energy intensiveness ratios shown earilier, a diesel train will produce 1.5 times as much air pollution and a diesel truck 4.8 times as much air pollition per-ton-mile as a tow and barges. In any event, no matter which kind of pollutant is of concern in a particular case, the efficiency of barging compared with other modes of freight transportation will result in reduced air emissions per ton-mile.

Barge Transportation and Cost Savings

A further benefit which can be attributed to the maintenance of navigation on the Upper Mississippi is in the savings in transportation costs, particularly for bulk commodities. Estimates of these savings have been made. One of these estimates the savings over the other various least cost alternatives of between 4.0 and 5.4 mills per ton-mile (UMRCBS, 1970). It is generally recognized that bulk commodities, particularly those having low value-to-weight ratios, are appropriate for barge transport. Coal, petroleum, and grain that have these characteristics are examples of such commodities that originate, terminate, or move through the St. Paul District pools on river barges.

Recreational Activities

Table 25 identifies the variety of recreational activities — from boating and sport fishing to sightseeing and camping — that may be helped or hindered by Corps' operations. Ideally it would be desirable to place dollar values on each of the benefits and costs to the recreational activities cited in Table 25 to weigh against the benefits of barge transportation made possible by maintaining the 9-foot channel. Unfortunately both conceptual problems and lack of precise data preclude such an analysis. The nature of these limitations can be understood by (1) looking initially at a theoretical approach of measuring the benefits and costs of recreational activities and (2) applying some of these ideas to the measurement of only one aspect of all recreation activities — sport fishing.

Applying even this theoretical framework to the 9-foot channel project presents both conceptual and data collection problems. For example, continuing to operate and maintain the 9-foot channel may hurt sport fishing because of the reduction in fish habitat. This means that the total value of sport fishing in the river should not be considered in the analysis. Rather, only the incremental increase or decrease in sport fishing attributable to present Corps' operations (not due to the initial lock and dam construction) should be weighed against those operations; no estimates are presently available to assess the effect of current Corps' operations on fish and wildlife. Also, reduced fish and waterfowl habitat may eventually increase some types of wildlife habitat. What the fisherman loses, the hunter, trapper and birdwatcher may gain. Never, however, will the newly-created terrestrial habitat be as productive as the marsh habitat was. Species diversity in the terrestrial habitat would be much less than in a marsh. Valuable fur-bearers such as mink, beaver and muskrat, for example, would be replaced with less valuable species.

This raises a second difficulty: How does one measure the total value of sport fishing on the river in order to start to measure the incremental portion attributable to Corps' operations? For sport fishing various measures have been identified, each having its own drawbacks (Clawson and Knetsch, 1966): gross expenditures by the fishermen, market value of fish caught, cost of providing the fishing opportunity, the market value as determined by comparable privately owned recreation areas, and the direct interview method — asking fishermen what hypothetical

price they would be willing to pay if they were to be charged a fee to fish.

If some average price per fisherman or trip were available, it still would be possible to assess the total value of sport fishing in the study area only if estimates of the number of sport fishermen or number of sport fishing trips were available. In the St. Paul District these estimates are available through sport fishery surveys for only three pools: Pool 4, Pool 5, and Pool 7. The most recent data available for these pools are for the 1967-68 year (Wright, 1970); comparable data for 1972-73 have been collected but are not expected to be published in report form until about December, 1973.

Valuing Sport Fishing in the Study Area

A variety of studies have been done on recreation and tourism in Minnesota and the Upper Midwest during the past decade (North Star Research Institute, 1966; Midwest Research Institute, 1968; Pennington, et al., 1969). For purposes of analyzing sport fishing and other recreational activities on the Upper Mississippi River, however, they have a serious disadvantage; these studies are generally limited to recreationers who have at least one overnight stay away from home. In the case of the St. Paul District, with the exception of campers and boaters on large pleasure craft with bunks virtually all river users are not away from home overnight and are omitted from such studies.

Information is then generally restricted to that available in the UMRCC sport fishing studies such as those shown below for 1967-68 (Wright, 1970):

Pool Number	Total Number of Fishing Trips	Value at $5.00 Per Trip[a]	Value at $1.50 Per Trip[b]
4	169,361	$846,805	$254,042
5	52,786	258,930	77,699
7	63,238	316,190	94,857

[a]Based on data reported in the "1965 National Survey of Fishing and Hunting" that the average daily expenditure for freshwater sport fishing was $4.98 per day.

[b]Based on data in Supplement No. 1 (1964) to Senate Decument 97 that provides a range of unit values of $0.50 to $1.50 a recreation day for evaluating freshwater fishing aspects of water resource projects.

Thus the sum of the values of sport fishing given above for these three pools varies from about $0.4 million to $1.4 million depending upon the valuation of a fishing trip. Assuming one of these values were usable, the researcher is still left with the task of determining the portion (either as a benefit or cost) of Corps' operations. With the limited funds available for the present research and the limited existing data, detailed analysis is beyond the scope of the present study.

Similar problems are present in evaluating the other recreational activities in the study area.

Cultural Sites

No attempt has been made in the present study to place dollar values on archaeological, historical, or cultural sites damaged or enhanced by Corps' operations. Rather, such sites have merely been identified, where existing data permit.

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7. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The most obvious resources lost because of the project include submarginal farm land and forest areas. Other resources are the gravel, cement, steel, limestone rubble, other materials, fossil fuels and man power necessary for the implementation of the project. Similar resources are expended annually for the maintenance of the project.

Less obvious is the flood storage volume of the flood plain which has been irretrievably lost to depositions of sand and silt. Also lost, of course, was a natural river which has now been harnessed, confined and subdued.

8. RECOMMENATIONS

Dredging and the placement of ultimate disposal of generated spoil is without doubt the No. 1 problem in the operation and maintenance of the 9-foot navigation project. There is great need for study and investigations of the merits of the alternatives suggested previously in this report.

The studies and investigations should be management oriented, that is, designed to explore solutions to the many facets involved. It should be possible for the Corps of Engineers to staff sufficiently, with professionals, to mount in-house investigations of these factors. Close liaison should be maintained with natural resource agencies and the academic community to correlate the many approaches for a whole environment.

The advantage of tooling up the table of organization of the Corps of Engineers to include the biological sciences would indicate to all that the Corps was giving equal time and energy to determine and ultimately place the needs of the environment in the same exposure as the purely engineering format of Corps operations.

The following is a list of studies and/or investigations, that would be of value in the program of dredge spoil disposal.

The Chippewa River is a fertile field for study in the needs and methods of controlling erosion at its source. Although it is presumed that the Soil Conservation Service could, and should have addressed itself to such a problem, it has not. Therefore, a Corps-sponsored study should bring out much good information toward the ultimate solution of the contribution of the tributary streams of the Mississippi River to the sediment problem.

A comprehensive survey and testing program concerning the intrinsic value of dredge spoil should be initiated to meet the needs of local and state governments, commerce and industry. Such needs are now being met by degrading the off-river environment by mining aggregates to meet the above needs.

The Corps, recognizing its role as the ultimate responsible agency for disposition of dredge spoil should assume responsibility for mounting a comprehensive dredge spoil disposal survey as often as necessary to accomplish environmental enhancement of the disposal program. The survey should be the consensus of engineering and environmental disciplines,

merging their evaluations of the problem and reaching decisions least detrimental to either.

In anticipation of ultimately moving spoil long distances from the cutter head, new equipment must be found or designed to meet this requirement. The use of spoil outside the flood plain may well require newly-planned equipment to move it by other than the well-established discharge pipe. By the same token, new equipment such as relay pumps and lengthened transport pipe to move spoil greater distances should be studied as a method whereby beneficial uses of spoil may be attained for wildlife or recreational enchancement.

The Corps, recognizing that it is creating (or has created) an "attractive nuisance" in the form of sandbars along either side of the navigation channel, should fund a recreation development and maintenance program to accommodate the using public.

The development of one sophisticated recreation center complex in each pool could provide for many thousands of recreational use days annually while being a depository for hundreds of thousands of cubic yards of dredge spoil, in this case properly contained by accepted and approved methods. Such a facility should provide camping, picnicking, boating and water skiing bases, fishing piers and interpretation centers of the river scene. From this center, hiking trails, power boat and canoe trails could originate, providing additional recreational outlets to those interested in more than the sedentary activity of lying on the beach.

Modern facilities such as electricity, toilet facilities and communications can be provided at such a center within technology now available, with little or no degradation of the environment. At the outset, these centers might make landside access feasible and desireable.

Studies leading toward fixation of dredge spoil at the deposition site are urgently needed. Wind and water erosion of dredge spoil deposits is still an unknown quantity, because no agency has yet studied the problem. There is a need for such and it is difficult to comprehend that the staff of the Corps has not instituted a comprehensive study to determine the loss from unprotected spoil piles. If such loss is of major proportion (and the investigators believe it is), methods should have been developed to lessen the loss, thus decreasing the cost and energy expenditure of rehandling the same spoil repeatedly.

Experimental dredge spoil sites should be designated, wherein the spoil should be contained in various ways. If dredge spoil is to be continually placed in the flood plain, it should be piled higher. Containment could be accomplished with gabions or with other forms of rock work.

Concentric rings of live willow saplings could be staked around the point where spoil is being discharged. The saplings would decrease the velocity of the discharge water and thus increase the grade of the spoil pile. Thus, the pile would not extend outward as far. The partially buried willows would take root and prepare the area for subsequent spoilings.

The tops of contained spoil piles should be elevated above flood level, and they should be capped with soil so that they can be vegetated either as grassland or as forest. Such areas would be utilized by nesting waterfowl, other forms of wildlife and by humans.

Experiments should be conducted to determine which types of vegetation would be most effective in stabilizing dredge spoil deposits.

The Corps should be budgeting for the future in the area of conducting the studies and investigations listed above. Too often, adversaries hear from the Corps that it is the environmentalists who should petition Congress for monies to fund the programs suggested to eliminate environmental degradation caused by channel maintenance of the 9-foot project.

The Congress of the United States has long been interested in programs which involve youth in experiences which develop greater appreciation for their country. In this vein, the Congress has instituted programs for the various federal agencies to employ youths in correcting deficiencies in the management of natural resources. The Youth Conservation Corps is the vehicle favored by Congress.

The opportunity for youth to preserve the Mississippi River ecosystems lies within the grasp of the Corps of Engineers. Establishment of a YCC project to stabilize dredge spoil and natural sand banks within the Mississippi and Chippewa valleys would: (1) decrease the energy drain made necessary by channel dredging, and (2) expose young people to the

concern for protecting the environment for their future.

Elements within the Corps' table of organization are apparently in favor of expanding their responsibilities toward management of the environment. This responsibility, if accepted, would indicate a recognition of the need for engineers and ecologists to combine their efforts for the general public good.

It should be easily recongizeable that Congress under several acts and other legislation, authorized the Corps almost complete mastery over the Mississippi River. This authorization, however, was not intended to permit the Corps to treat all aspects of the river environment, other than navigation, with indifference or disdain. It is in the interest of the general public in the river environment, that the Corps should be doing all in its power to fund, through upcoming budgets, actions designed to preserve and enhance that environment for all people.

The observation platforms are relished by visitors to the locks where closeup views of the operations are afforded. There is considerable lack of information available to these visitors as to background and Corps policies on its management of facilities in the public interest. An expansion of information dissemination at these locations is highly recommended.

A review of the methods used in gathering public use days information is recommended to update the information available on which to justify line items in budgets having to do with recreational use of the project.

Correlation with State Departments of Natural Resources and the Bureau of Sport Fisheries and Wildlife exists but refinements to produce more accurate information is in order.

The Corps currently has no forestry or timber management plan operating on project levels. The Bureau of Sport Fisheries and Wildlife has an ongoing program of timber management on its fee lands wherein the welfare of all resources-timber harvest, forest regeneration, wildlife needs and the like are all encompassed in a comprehensive management plan, developed by a forester in consultation with a wildlife manager from the Upper Mississippi Wildlife Refuge staff. The need for wood fiber is such that a forest management plan should be in effect on Corps lands, and could, if arranged, be handled most economically by trained professionals on the Wildlife Refuge Staff.

APPENDIX A

Marsh and Aquatic Plants in Pools 4 - 9 (Green, 1947)

Marsh Plants	%	Aquatic Plants	%
Zizania	1	Potamogeton americanus	17
Leersia	1	Potamogeton pectinatus	6
Echinochloa	.25	Potamogeton foliosus	6
Phalaris	1	Potamogeton zosteriformis	.5
Phragmites	5	Potamogeton crispus	1
Other Graminae	2	Potamogeton richardsoni	trace
Scirpus fluviatilis	28	Potamogeton epihydrus	trace
Scripus validus	3	Heteranthra dubia	3
Eleocharis	trace	Vallisneriaspiralis	trace
Carex	2	Nitella	trace
Sparganium	7	Naias	2
Sagittaria	47	Zannichellia	trace
Typha	trace	Elodea	13
Potamogeton pennsylvanicum	trace	Lemnaceae	7
Potamogeton muhlenbergii	trace	Ceratophyllum	21
Polygonum spp.	1	Myriophyllum	trace
Pontederia	trace	Utricularia	trace
Rumex	trace	Ranunculus	-
Compositae	2	Nelumbo	18
		Castalia	trace
		Nymphaea	3
		Algae	1

Reptiles and Amphibians of the Study Area

Common Name	Scientific Name	Abundance
Snapping Turtle	*Chelydra serpentina*	Common
Wood Turtle	*Clemmys insculpta*	Rare
Map Turtle	*Graptemys geographica*	Common
False Map Turtle	*Graptemys pseudogeographica*	Common
Painted Turtle	*Chrysemys picta*	Common
Blanding's Turtle	*Emydoidea blandingi*	Common
Smooth Softshell	*Trionyx muticus*	Common
Spiny Softshell	*Trionyx spinifer*	Common
Six-lined Racerunner	*Cnemidophorus sexlineatus*	Occasional
Northern Water Snake	*Natrix sipedon sipedon*	Common
Brown (DeKay's) Snake	*Storeria dekayi*	Uncommon
Red-bellied Snake	*Storeria occipitomaculata*	Uncommon
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*	Abundant
Eastern Hognose Snake	*Heterodon platyrhinos*	Occasional
Blue Racer	*Coluber constrictor foxi*	Common
Fox Snake	*Elaphe vulpina*	Occasional
Black Rat Snake	*Elaphe obsoleta obsoleta*	Occasional
Bullsnake	*Pituophis melanoleucus sayi*	Common
Eastern Milk Snake	*Lampropeltis doliata triangulum*	Occasional
Massasauga	*Sistrurus catenatus*	Occasional

Common Name	Scientific Name	Abundance
Timber Rattlesnake	Crotalus horridus horridus	Occasional
Mudpuppy	Necturus maculosus	Occasional
Eastern Tiger Salamander	Ambystoma tigrinum tigrunum	Common
American Toad	Bufo americanus	Common
Spring Peeper	Hyla crucifer	Abundant
Gray Treeforg	Hyla versicolor	Common
Western Chorus Frog	Pseudacris triseriata triseriata	Common
Green Frog	Rana clamitans melanota	Common
Leopard Frog	Rana pipiens	Common

Birds Most Commonly Seen in the Study Area

Pied-billed Grebe
Double-crested Cormorant
Great Blue Heron
Green Heron
Common Egret
Black-crowned Nigh Heron
American Bittern
Whistling Swan
Canada Goose
Snow Goose
Blue Goose
Mallard
Black Duck
Gadwall
Pintail
Green-winged teal
Blue-winged Teal
American Widgeon
Shoveler
Wood Duck
Redhead
Ring-necked Duck
Canvasback
Lesser Scaup

Common Goldemeye
Bufflehead
Ruddy Duck
Hooded Merganser
Common Merganser
Turkey Vulture
Rail-tailed Hawk
Red-shouldered Hawk
Broad-winged Hawk
Balk Eagle
Marsh Hawk
Osprey
Sparrow Hawk
Ruffed Grouse
Ring-necked Pheasant
Sora Rail
American Coot
Semipalmated Plover
Killdeer
Common Snipe
Spotted Sandpiper
Solitary Sandpiper
Lesser Yellowlegs
Least Sandpiper

Semipalmated Sandpiper
Herring Gull
Ring-billed Gull
Forster's Tern
Common Tern
Black Tern
Mourning Dove
Yellow-billed Cuckoo
Black-billed Cuckoo
Screech Owl
Great Horned Owl
Barred Owl
Whip-poor-will
Ruby-throated Hummingbi
Belted Kingfisher
Yellow-shafted Flicker
Red-bellied Woodpecker
Red-headed Woodpecker
Yellow-bellied Sapsuck
Hairy Woodpecker
Downy Woodpecker
Eastern Kingbird
Great Crested Flycatch
Eastern Pheobe

Birds Most Commonly Seen in the Study Area

Traill's Flycatcher
Eastern Wood Pewee
Horned Lark
Tree Swallow
Bank Swallow
Barn Swallow
Purple Martin
Blue Jay
Common Crow
Black-capped Chickadee
Tufted Titmouse
White-breasted Nuthatch
Brown Creeper
House Wren
Long-billed Marsh Wren
Catbird
Brown Thrasher
Robin
Wood Thrush
Hermit Thrush
Swainson's Thrush
Gray-cheeked Thrush
Veery
Eastern Bluebird
Rudy-crowned Kinglet
Cedar Waxwing
Loggerhead Shrike

White-eyed Vireo
Yellow-throated Vireo
Red-eyed Vireo
Black-and-white Warbler
Prothonotary Warbler
Tennessee Warbler
Yellow Warbler
Magnolia Warbler
Myrtle Warbler
Black-throated Green Warbler
Blackburnian Warbler
Blackpoll Warbler
Palm Warbler
Northern Waterthrush
Yellowthroat
Wilson's Warbler
Canada Warbler
American Redstart
House Sparrow
Eastern Meadowlark
Red-winged Blackbird
Baltimore Oriole
Rusty Blackbird
Common Grackle
Brown-headed Cowbird
Cardinal
Rose-breasted Grosbeak

Indigo Bunting
Dickcissel
American Goldfinch
Vesper Sparrow
Slate-colored Junco
Tree Sparrow
Harris' Sparrow
White-throated Sparrow
Lincoln's Sparrow
Swamp Sparrow
Song Sparrow

Mammals of the Study Area

Common Name	Scientific Name	Abundance
Eastern Gray Squirrel	*Sciurus carolinensis*	common
Eastern Fox Squirrel	*Sciurus niger*	common
Red Squirrel	*Tamiasciurus hudsonicus*	rare
Southern Flying Squirrel	*Glaucomys volans*	common
Plains Pocket Gopher	*Geomys bursarius*	occasional
Beaver	*Castor canadensis*	common
Western Harvest Mouse	*Reithrodontomys megalotis*	uncommon
Deer Mouse	*Peromyscus maniculatus*	common
White-footed Mouse	*Peromyscus leucopus*	common
Southern Bog Lemming	*Synaptomys cooperi*	common
Meadow Vole	*Microtus pennsylvanicus*	common
Prairie Vole	*Pedomys ochrogaster*	common
Pine Vole	*Pitymys pinetorum*	occasional
Muskrat	*Ondatra zibethicus*	common
Norway Rat	*Rattu norvegicus*	common
House Mouse	*Mus musculus*	common
Meadow Jumping Mouse	*Zapus hudsonius*	common
Nutria	*Myocaster coypus*	rare
Coyote	*Canis latrans*	occasional
Red Fox	*Vulpes fulva*	common
Gray Fox	*Urocyon cinereoargenteus*	common

Mammals of the Study Area (continued)

Common Name	Scientific Name	Abundance
Raccoon	*Procyon lotor*	common
Least Weasel	*Mustela rixosa*	uncommon
Mink	*Mustela vision*	common
Badger	*Taxidea taxus*	uncommon
Spotted Skunk	*Spilogale putorius*	occasional
Striped Skunk	*Mephitis mephitis*	common
River Otter	*Lutra canadensis*	occasional
Bobcat	*Lynx rufus*	rare
Virginia Opossum	*Didelphis marsupialis*	common
Masked Shrew	*Sorex cinereus*	common
Shorttail Shrew	*Blarina brevicauda*	common
Least Shrew	*Cryptotis parva*	common
Eastern Mole	*Scalopus aquaticus*	common
Starnose Mole	*Condylura cristate*	rare
Little Brown Myotis	*Myotis lucifugus*	common
Keen Myotis	*Myotis keenii*	common
Eastern Pipistrel	*Pipistrellus subflavus*	uncommon
Big Brown Bat	*Eptesicus fuscus*	common
Red Bat	*Lasiurus borealis*	common
Hoary Bat	*Lasiurus cinereus*	rare
Eastern Cottontail	*Sylvilagus floridanus*	common

Mammals of the Study Area (continued)

Common Name	Scientific Name	Abundance
Whitetail deer	*Odocoileus virginianus*	common
Woodchuck	*Marmota monax*	common
Thirteen-lined Ground Squirrel	*Citellus franklinii*	rare
Eastern Chipmunk	*Tamias striatus*	common

Organisms collected by Watkins (1969) from Artifical Substrate Samplers In the Main Channel of Pool 6, 1966-1967

CLASS	ORDER	FAMILY	GENUS & SPECIES
Crustacea			
	Isopoda		
		Asellidae	*Asellus* sp.
	Amphipoda		
		Talitridae	*Hyallela azteca*
Arachnoidea			Arachnoidea sp.
Oligochaeta			
		Naidiae	*Chaetogaster* sp.
Turbellaria			
		Planariidae	*Dugesia* sp.
Hydrozoa			
		Hydridae	*Hydra* sp.
Insecta			
	Plecoptera		
		Perlodidae	*Isoperla* sp.
	Ephemeroptera		
		Siphlonuridae	*Isonychia* sp.
		Baetiscidae	*Baetisca bajkovi*
		Tricorythidae	*Tricorythides* sp.
		Baetidae	*Baetis* sp.
		Heptageniidae	*Stenonema* sp.

CLASS	ORDER	FAMILY	GENUS & SPECIES
			Heptagenia sp.
		Ephemerellidae	*Ephemerella* sp.
		Caenidae	*Caenis* sp.
	Trichoptera		
		Leptoceridae	*Oecetis* sp.
		Hydropsychidae	*Hydropsyche frisoni*
			Hrdropsyche simulans
			Hydropsuche orris
			Cheumatopsyche campyla
			Potamyia flava
		Hydroptilidae	*Agraylea* sp.
			Oxyethira sp.
		Psychomyiidae	*Psychomyiid Genus A*
			Polycentropus remotus
	Diptera		
		Chironomidae	*Tanytarsus* sp.
			Coelotanypus sp.
			Corynoneura sp.
			Pentaneura sp.
			Cryptochironomus sp.
			Paratendipes sp.
			Stendochironomus sp.
			Tanypus sp.

CLASS	ORDER	FAMILY	GENUS & SPECIES
			Heptogyia sp.
	Odonata		
		Lestidae	*Lestes* sp.
		Libellulidae	
			Libellula sp.
	Lepidoptera		
		Pyralididae	*Cataclysta* sp.
			Nymphula sp.

Total Macro-invertebrates Collected by Ebert (1965) at Two Mississippi River Sampling Stations

ORGANISMS	STATION 764.5	STATION 760.5
Trichoptera		
Agraylea	14	20
Cheumatopsyche	28	1
Hydropsyche	19	1
Ephemeroptera		
Heptagenia	5	-
Isonychia	2	-
Tricorythodes	9	-
Plecoptera		
Perlesta	2	-
Coleoptera		
Agabus	1	-
Diptera		
Simulium	1	1
Calopsectra	1	-
Cricotopus	25	4
Hydrobaenus	3	-
Tendipes	50	26
Polypedilum	-	1
Odonata		
Coenagrion	-	1
Isopoda		
Asellus	4	-

ORGANISMS	STATION 764.5	STATION 760.5
Amphipoda		
Gammarus	18	13
Turbellaria		
Planaria	-	3
Annelida	16	9
Hydrozoa	15	25
Gastropoda		
Physa	1	24

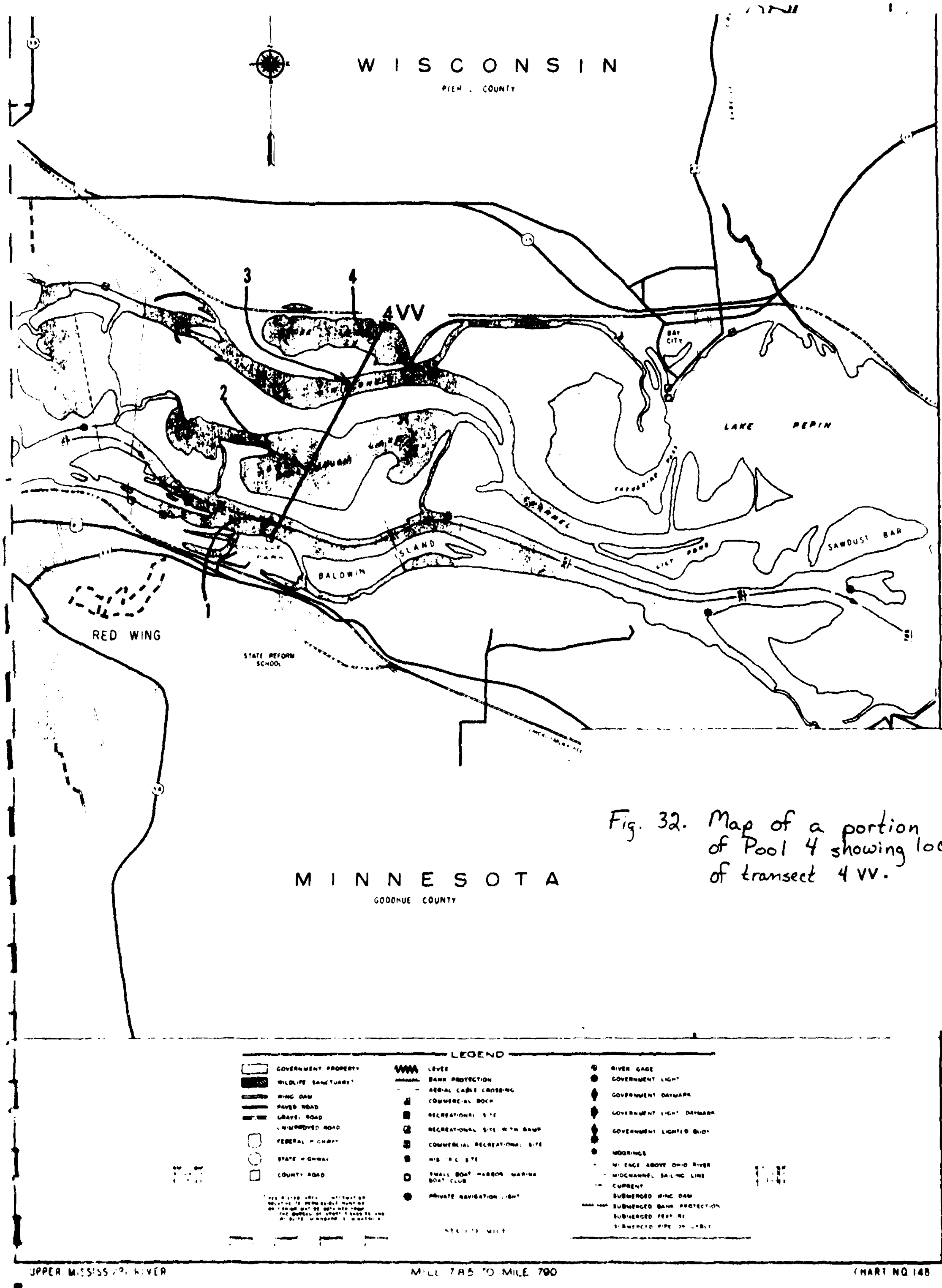

Fig. 32. Map of a portion of Pool 4 showing location of transect 4 VV.

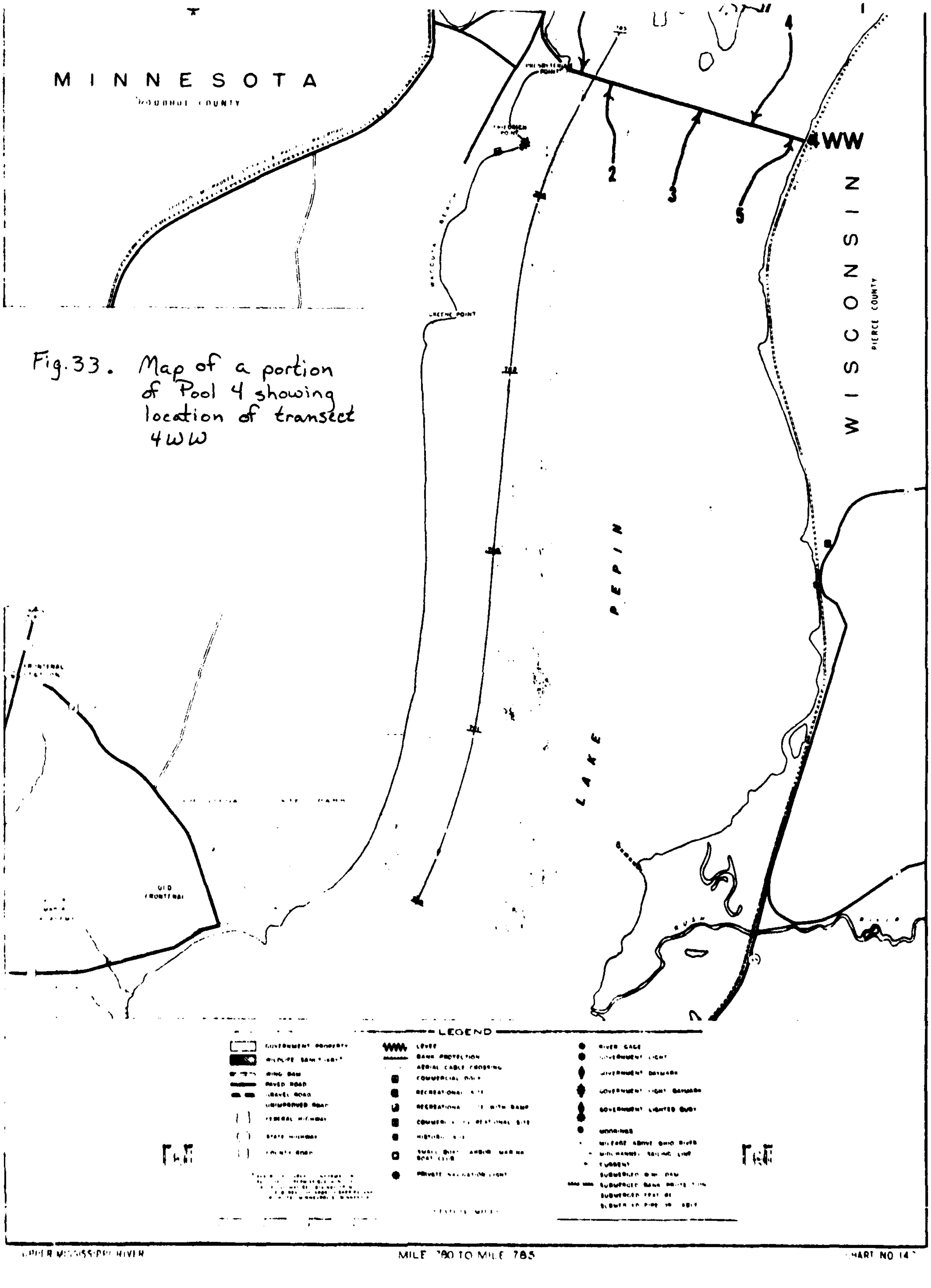

Fig. 33. Map of a portion of Pool 4 showing location of transect 4WW

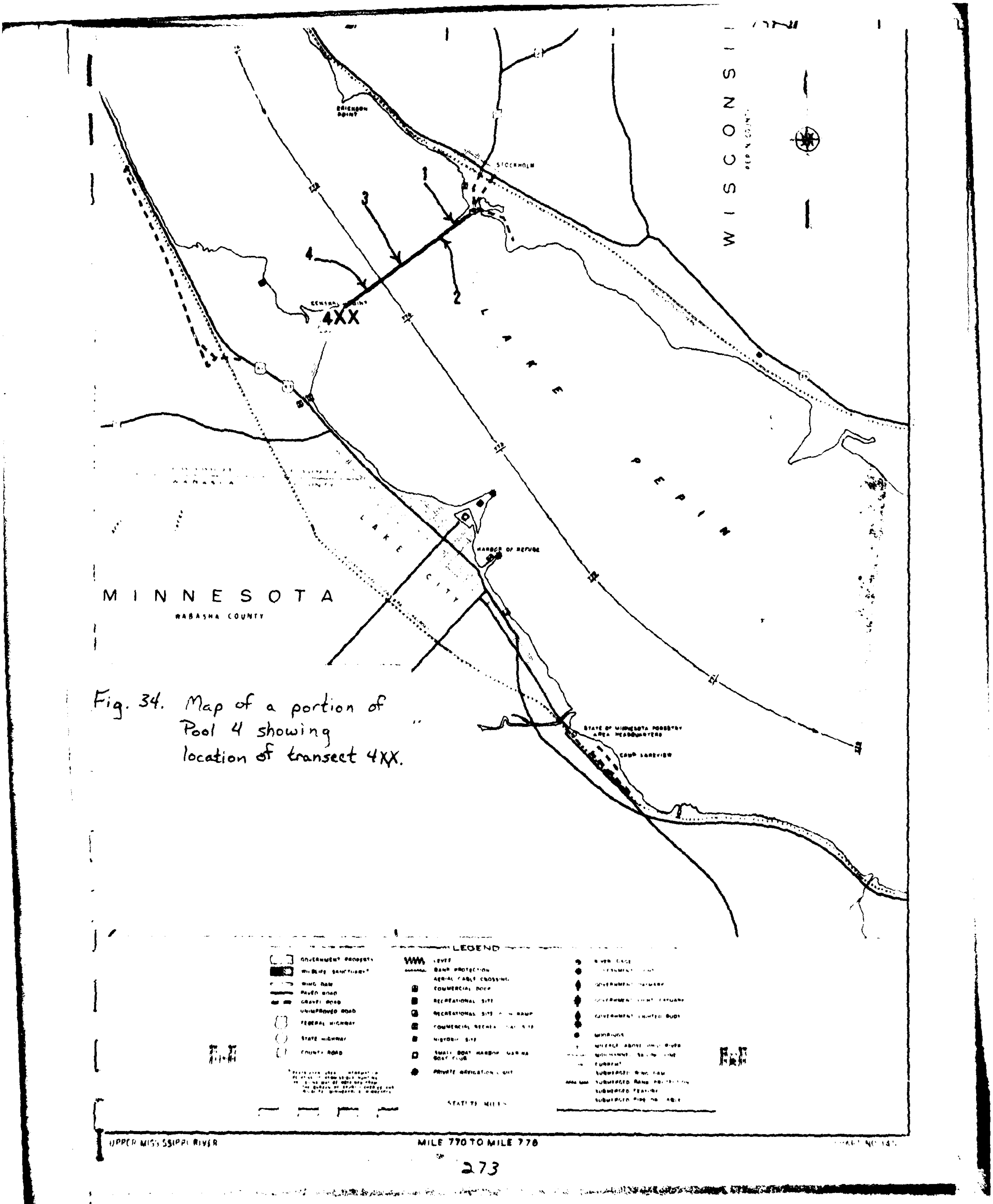

Fig. 34. Map of a portion of Pool 4 showing location of transect 4XX.

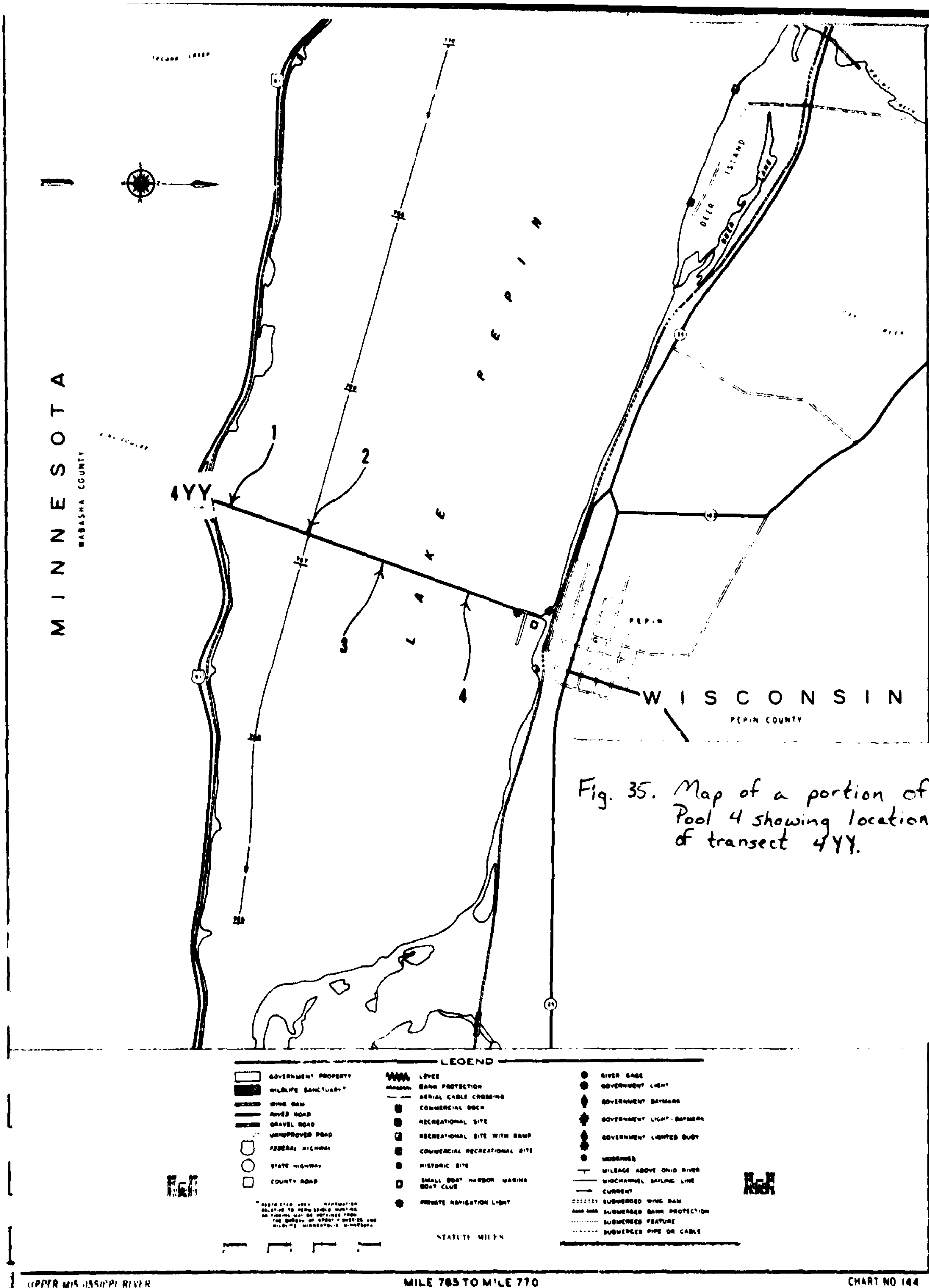

Fig. 35. Map of a portion of Pool 4 showing location of transect 4YY.

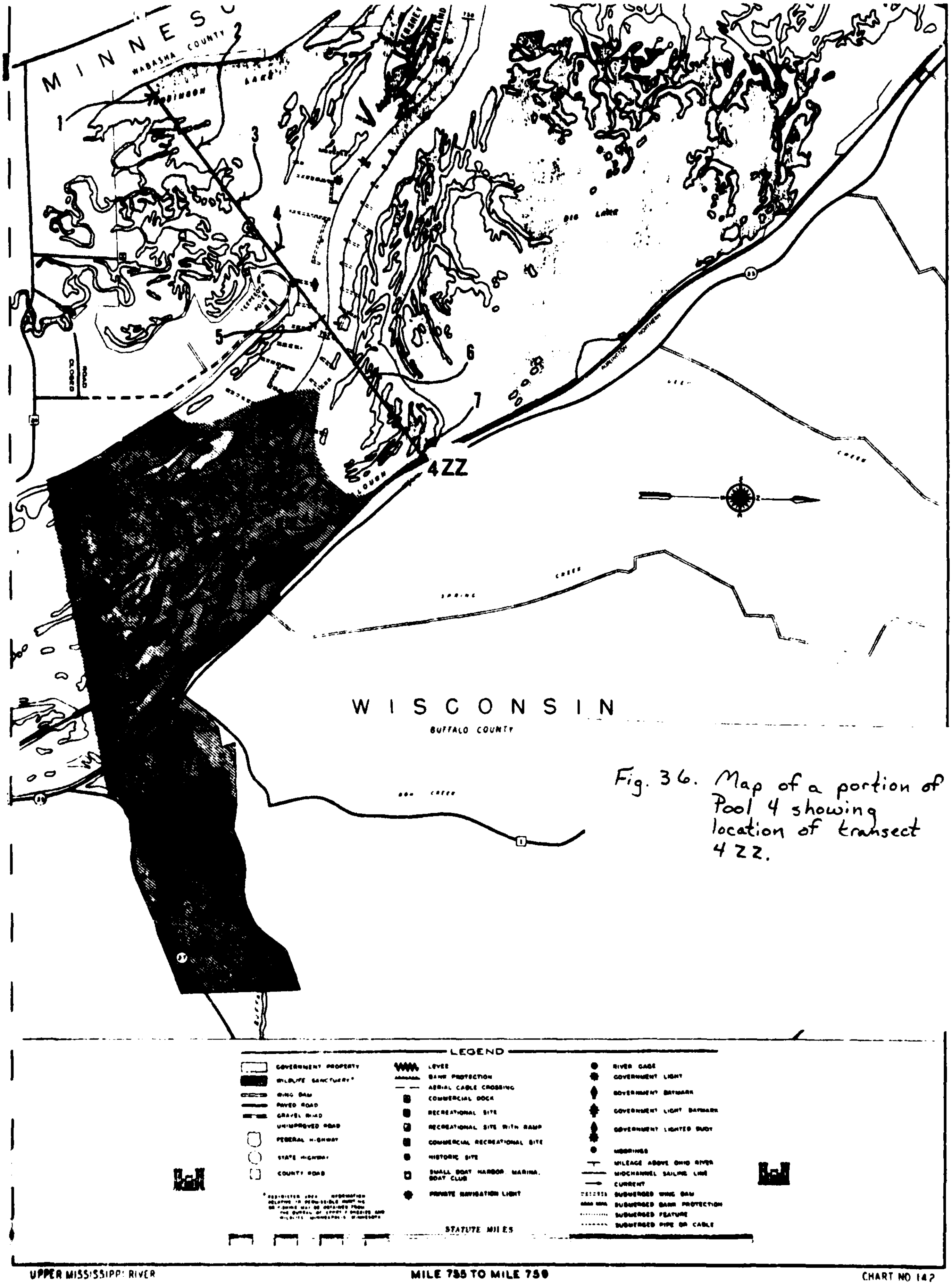

Fig. 36. Map of a portion of Pool 4 showing location of transect 4ZZ.

UPPER MISSISSIPPI RIVER — MILE 755 TO MILE 759 — CHART NO 142

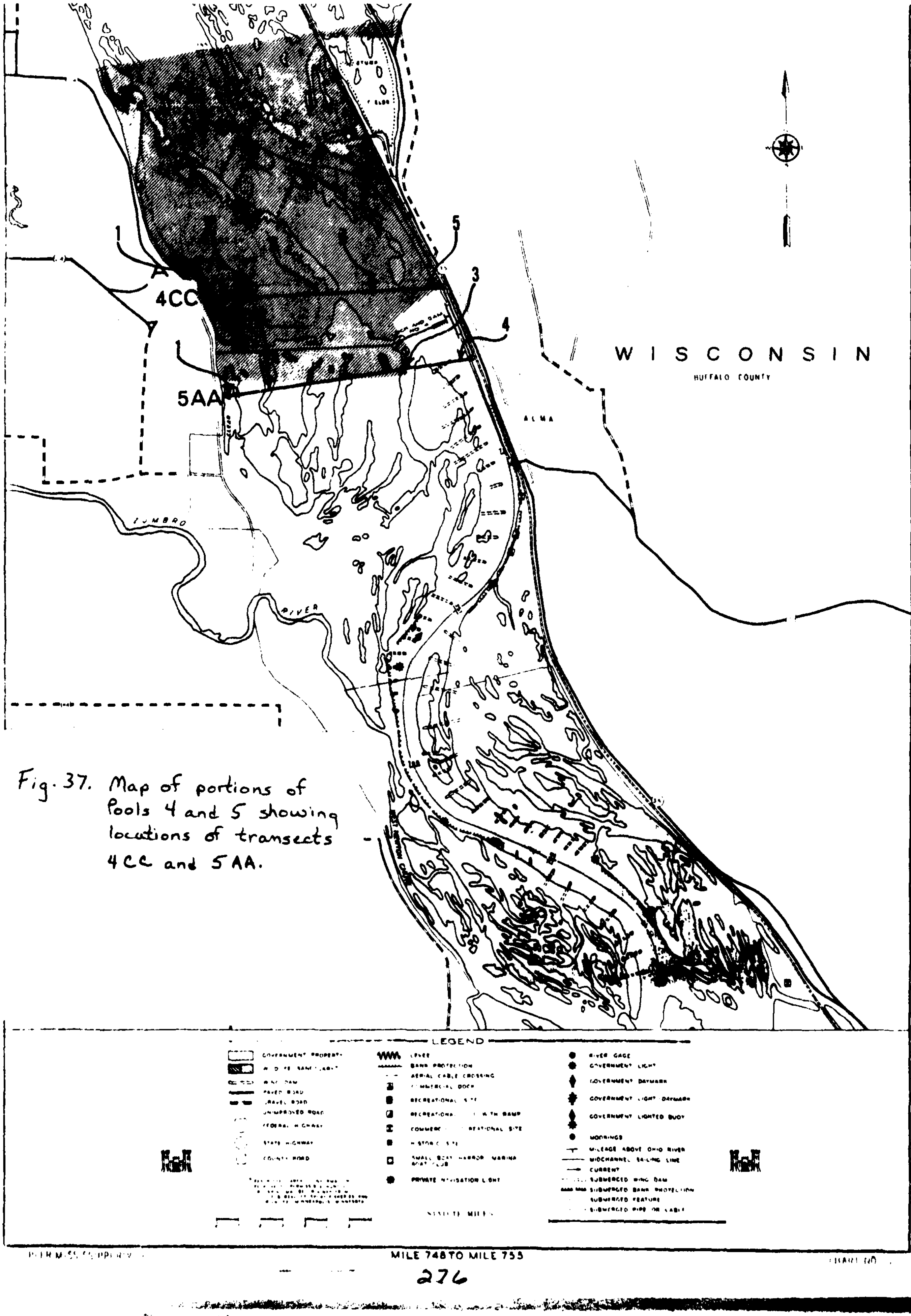

Fig. 37. Map of portions of Pools 4 and 5 showing locations of transects 4CC and 5AA.

Table 26 . Descriptions of transects within the study area.

TRANSECT 4VV

The base point for this transect was the northern corner of an abandoned concrete boat ramp in Colville Park. The park lies just east of Red Wing on Highway 61. The boat ramp lies on the east side of the river entrance to the park marina. The transect line which was established on July 12, 1973, extends across the main channel in a direction of $N5^{\circ}E$ into a flood plain forest and across the middle of a back water slough, referred to as Lower Lake. Access to Lower Lake through small channels, 3 4/5 and 1 1/8 miles up river, was complicated by rock wing dams projecting across the mouths of both streams. The maximum depth of Lower Lake along the transect line was 3 feet. A rock wing dam was found between 1/4 and 3/8 mile west of the transect line and it lay about 1 to 2 feet under the surface. The line then moved into another flood plain forest and across an abandoned channel referred to as the Wisconsin Channel. Leaving Lower lake to get to the Wisconsin Channel has to be done through the east channel due to low water in Upper Lake. The Wisconsin Channel at the transect point was approximately 1/8 mile wide. Both sides of the channel are bordered by flood plain forest and trees have begun to fall in on both banks. Current in the Wisconsin Channel was undetectable, but the channel was 12 feet deep. The line again went across a flood plain forest and into a back water slough called Goose Lake. The end of the transect was a cabin set back in scattered trees with a sandy beach in front. No permanent boat launch or other such markers could be observed.

TRANSECT 4WW

This transect was begun on the Minnesota side of the river at Presbyterian Point and was established on July 12, 1973. This point was very close to what could be called the beginning of Lake Pepin. Medium to coarse sand with rock and debris made up the tip of the point and extended down both sides. The middle regions of the peninsula, 15 yards from the water edge were grown up with large trees and other flood plain vegetation. Approximately 100 yards down the east side of the point was a large summer home set on concrete pillars. The transect line projected from the tip of Presbyterian Point across the main channel in a direction of $N26^{\circ}E$. The reference point on the Wisconsin side was a red and white radio tower on the top of the bluff. The river bank on this side was bounded by railroad tracks usually with no trees between the tracks and the water edge. At the end point of the transect, however, large trees were growing between the tracks and water for a length of approximately 50 yards. The line came within 1/4 to 3/8 mile of the eastern tip of Saw Dust Island located up river from the transect.

TRANSECT 4XX

The base point for this transect was established on July 12, 1973, on the Wisconsin shore at the tip of a stone dike located at the town of Stockholm, Wisconsin. The dike was approximately 4 feet above the surface and extended 1/8 mile out into Lake Pepin. The transect line then extended across the lake to the tip of Central Point, on the Minnesota side. The point was composed of medium to course sand with traces of rock and detritus. The closest vegetation to the tip of the point was approximately 25 yards. The distance between water and vegetation decreased, however, moving southwesterly down the banks of the peninsula. The southern face of the point was lined with cottages, beginning within 75 yards of the end of the transect. On the western face at the junction of vegetation and sand, large pieces of concrete slabs had been piled.

TRANSECT 4YY

The base point for this transect was the northwest corner of a railroad trestle located 6.2 miles down river from Lake City on Highway 61. The trestle crossed over King Coulee Creek which was very slowly flowing on July 11, 1973, the date the transect was established. The line extended across Lake Pepin to the tip of a rock dike protruding 1.8 mile into the river at the Wisconsin town of Pepin. The beach area to the west of the dike was sandy and used for swimming. Approximately 400 feet down the east side of the dike was another rock wall running perpendicular to the first. This wall was acting as a break water protecting the Pepin Marina, and was approximately 1000 feet long.

TRANSECT 4ZZ

Transect 4ZZ was not layed out in a straight line, but was formed by two straight line segments. The first segment was based on a reference point (a red and white radio tower) located at the top of the Minnesota bluff. The other end point for this segment was the most northwesterly tip of Teepeeota Point. A red panelled house, on the shore of Robinson Lake, lay directly between the reference point and the end point, and the house became the actual base point for this segment of the transect. Robinson Lake was more slough-like than lake-like and was very shallow and weedy. The transect line ran across a maze of shallow weed beds in a direction of N70^{o}E.

The next segment of the transect ran from the northwesterly tip of Teepeeota Point in a direction of N58^{o}E. The line crossed a maze of flood plain islands and backwater sloughs and ended on the Wisconsin side at a boat landing. The boat landing was located on Buffalo Slough and was constructed of gravel and surrounded by large trees. The transect was established on July 11, 1973.

TRANSECT 4CC

This transect, which was established on June 29, 1973, was run along the up-river side of Lock and Dam number 4. The base point was located 650 feet south of an abandoned boat ramp on the Minnesota side of Peterson Lake. The ramp was constructed of asphalt near the top and a mixture of large rocks and gravel closer to the water's edge. Vegetation had over grown the ramp in several places. The lake contained many stumps, some of which were protruding above the surface of the water. The line extended in a direction of N85°E to an end point which was the 400-foot Lock and Dam marker on the Wisconsin side of the river. This point was near the northern end of the town of Alma. The bank of the river at this point was composed of large rocks, which acted as a retaining wall. At the mid-point of the transect the line passed very close to the southern tip of a flood plain island. This island was about 1/2 mile long and never more than 1/8 mile wide. It separated Peterson Lake from the channel of the river.

10. APPENDIX B: ARCHAEOLOGICAL BACKGROUND INFORMATION

Archaeological and historic sites of importance consist of such diverse elements as prehistoric village sites, petroglyphs (rock pictures), burial mounds, log cabins, forts, and so forth. Sites of significance may date from thousands of years ago to very recent times. Interest in studying elements of human history also varies as much with the times as interest in studying elements of natural history.

STUDIES IN THE LATE 1800's: THE LEWIS AND HILL SURVEY

Fortunately for our study now there was a strong interest in the late 19th Century in burial mounds; a massive study was pursued for approximately 20 years by Alfred J. Hill and Theodore H. Lewis. The extent of their work is best understood by examining a few of their manuscripts, a few samples of which are reproduced in this report. In 1928, Charles R. Keyes wrote of their accomplishments:

> "The great extent of the archeological survey work accomplished by Lewis and Hill cannot be appreciated except through an extended examination of the large mass of manuscript material that has been preserved. This consists approximately of the following forty leather-bound field notebooks well filled with the original entries of the survey; about a hundred plats of mound groups drawn on a scale of one foot to two thousand; about eight hundred plats of effigy mounds (animal-shaped mounds from Minnesota, Wisconsin, Iowa, and Illinois) on a scale of one foot to two hundred; about fifty plats of "forts" (largely village sites of the Mandan type) and other inclosures on a scale of one foot to four hundred; about a hundred large, folded tissue-paper sheets of original, full-size petroglyph rubbings with from one to six or more petroglyphs on each; about a thousand personal letters of Lewis to Hill; four bound "Mound Record" books made by Hill and in his handwriting; eight large, well filled scrapbooks of clippings on archeological matters made by Lewis; numerous account books, vouchers, and other miscellany...

"A single sheet of summary found among the miscellaneous papers of the survey, apparently made by Lewis, is eloquent in its significance. Tabulated by years and place of entry the mounds alone that were actually surveyed reach a grand total of over thirteen thousand--to be exact, 855 effigy mounds and 12,232 round mounds and linears...

"The survey is quite full for Minnesota, where work was done in all but three counties of the state, resulting in records of 7,773 mounds, besides a number of inclosures... much information was also gathered from the river counties of Iowa, Nebraska, Kansas, and Missouri. In Wisconsin the survey touched more than two-thirds of all the counties, mostly in the field of the effigy mounds in the southern half of the state, where the records supply detail for no less than 748 effigies and 2,837 other mounds. Iowa was explored most fully in the northeastern counties as far south as Dubuque, yielding data on 61 effigy mounds, 553 other mounds, and several inclosures. ...the survey yielded its richest results in Minnesota, the eastern parts of the Dakotas, northeastern Iowa, and the southern half of Wisconsin..." [Surveys were also conducted in the Dakotas, Manitoba, Missouri, Nebraska, Kansas, Illinois, Indiana, and Michigan--in all, eighteen states.]

"The strength of the survey consists, first of all, in the dependability of Lewis as a gatherer of facts... he worked as a realist, measuring and recording what he saw with painstaking accuracy and unwearying devotion... And the fact that these surveys were made at a time when a large number of mound groups that have since disappeared, or all but disappeared, were still intact, gives the work of Lewis and Hill an incalculable worth... So far as Iowa is concerned, something like half of the antiquities of the northeastern part of the state are recoverable only from the manuscripts of the Northwestern Archeological Survey..."

A typical description of the reporting format followed by Lewis and Hill is reproduced here:

[IN: MOUNDS IN DAKOTA, MINNESOTA AND WISCONSIN]

3. OTHER MOUNDS IN RAMSEY COUNTY, MINNESOTA.

At the lower end of the Pig's Eye marsh already mentioned, there stood (April, 1868) an isolated mound, not situated on the bluffs, but below them, near their foot, at the highest part of the river bottom on the sloping ground half-way between

the military road and the road-bed of the St. P. & C. R. R., then in course of construction, and distant about three hundred and fifty feet southward from the culvert on the former. It was in a cultivated field, and had itself been plowed over for years; yet it had still a mean height of six and a half feet; its diameter was sixty-five feet. The top of it was only thirty-one feet above the highwater of the Mississippi, according to the levels taken by the railroad engineers. The location of the mound, according to U. S. surveys, was on the N. 1/2 of SE. 1/4 of Sec. 23, T. 28, R. 22, and about one mile north of Red Rock landing. Mr. J. Ford, one of the old settlers of the neighborhood, said that a man named Odell had, some years previously, dug into it far enough to satisfy his curiosity, as the discovery of human bones clearly proved it to have been built for sepulchral purposes.

7. MOUNDS AT PRESCOTT, WISCONSIN.

At the angle formed by the confluence of the St. Croix and Mississippi rivers, on the eastern bank of the former, is the town of Prescott, Wisconsin. On May 13, 1873, three hours' time was employed in making such reconnaissance survey as was feasible of the mounds which stretch along the bluff on the Mississippi there. The smallest of them was about twenty-five feet diameter and one foot high, and the largest fifty-six feet diameter and four feet high, as nearly as could be then ascertained.

Pictographs were common on caves along the Mississippi River bluffs. Lewis and Hill recorded their locations and frequently the pictures themselves. Although specific reference was made to them in Houston, Winona, Washington, and Ramsey counties in Minnesota and Alamakee and Clayton counties in Iowa, it would be unwise to assume that they were limited to these locations.

Captain Carver, in 1766-67 explored a cave (in present day Ramsey County) as being of "amazing depth and containing many Indian hieroglyphics appearing very ancient." The cave, called by the Dakota "Wakan-teebe", became a popular tourist attraction in the 1860's. Railroad construction was responsible for its destruction by the 1880's.

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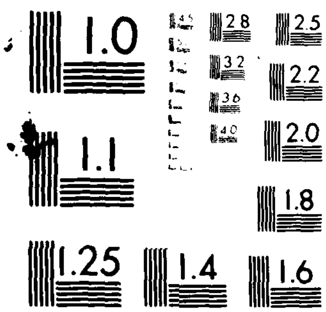

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

PRESENT CONSIDERATIONS

The difficulty, then, is not the absence of records of significant sites, but rather that records of thousands of sites exist. And although archaeologists have resurveyed some of the sited, vast areas have not been checked since the original surveys. The farmer, in the course of clearing and farming his land, is chiefly responsible for the destruction of the sites, and most of the sites have by now been destroyed.

MINNESOTA

This section contains information on significant archaeological and historic sites in Minnesota.

Background

This format evolved from problems encountered in developing an inventory of sites. The listing of reasons for not doing so which follows is included because it may shed some light on future problems also.

Original plans were made to provide an inventory of Minnesota archaeological sites which lie in the study area. This idea was abandoned, however, due to the following considerations:

1. The number of sites in close proximity to the river is large and the amount of work required to review existing records (beginning in the early 1800's) exceeds the value of such an inventory in this report;

2. The records are known to be incomplete in many cases, scanty for certain areas or incorrect so that reliability of the inventory is questionable;

3. Many sites once recorded have been destroyed by the action of others (not the Corps of Engineers) but the records have never been updated. Nor has there ever been a complete systematic inventory of archaeological sites in Minnesota.

4. In many cases the location of sites given is not sufficiently accurate to determine if the site is close enough to the river bank to be threatened. In some cases, where the bluffs are close to the river bed, a vertical elevation of many feet may effectively remove a site from any threats by water, dredge spoil, or construction. The records may not show this.

5. The Minnesota State Archaeologist is understandably reluctant to publish for public consumption a list or inventory of archaeological sites because of risk of robbery, despoliation, vandalism, or unauthorized unscientific excavation. Such cases have been known in the past. However, the State

Archaeologist and his staff have expressed the willingness and desire to assist individuals or government bodies in locating and identifying sites for preservation or excavation before destruction.

Impact on Prehistoric Archaeological Sites

Because the files of the State Archaeologist are located in the Twin Cities, it was possible to engage a professional archaeologist to investigate the current status of those archaeological sites in the Mississippi, Minnesota and St. Croix River areas in Minnesota. The report by consultant Jan Streiff is reproduced here in its entirety.

A Report of the Impact of the U. S. Army Corps of Engineers on Prehistoric Archaeological Sites on the Lower Mississippi, Lower St. Croix, and Lower Minnesota Rivers in Minnesota

By Jan E. Streiff, Archaeologist, Department of Anthropology, University of Minnesota, Minneapolis.

Introduction. There are approximately eighty-five (85) designated sites in the Corps of Engineers area under consideration (i.e., the Mississippi River from St. Anthony Falls to the Minnesota-Iowa border, the Minnesota River from Shakopee to Pike Island, and the St. Croix from above Stillwater to Prescott). The information on these sites has been collected since the late 1800's and all the data are filed in the Archaeology Laboratory at the University.

Although some of these sites have been revisited since being recorded, and a few have even been excavated, most have not been rechecked. Consequently there are many unknown things about most of the sites listed in this report. Ideally, a crew should have been sent out to resurvey the river valleys in

question, to determine if sites formerly recorded are still there and, if not, how they were destroyed--particularly if by the Corps of Engineers.

Since such an on-site survey was impossible at this time, the written records will have to suffice. I have organized the known sites into the three categories shown below.

Classification of Sites.

Group I. These are sites definitely known to have been destroyed by Corps of Engineers activities. There are nine (9) of these sites.

Group II. These are sites in the area under consideration which should not be affected by the Corps because they appear too high above the river channels. Although they may never be flooded by raised water levels, they should be kept in mind as possibly being destroyed by borrow activity, dredging, etc. There are six (6) of these sites.

Group III. This is the largest group of sites (73) within the Corps of Engineers area. This is the group for which no definite classification can be given. There are many reasons:

a. our site location description is too vague to determine if the site is or was in danger.

b. sites which were destroyed, such as the mound groups at Dresbach, but where we cannot determine if the destruction was carried out by the Corps of Engineers dam construction or by some unrelated project.

c. sites, such as those on Pig's Eye Island, which have not been reexamined since recorded but are so located as to be assured destruction by a fluctuation in the river level

or at least damaged by erosion by the river. Any dredging of the river and subsequent depositing of the debris on the nearby shore would undoubtedly cover the site.*

The Effect of Corps of Engineers Activities on Archaeological Sites by Pool. The following chart is a breakdown by pool of archaeological sites affected by the Corps of Engineers. The sites are listed using the groupings defined above.

Pool #	Group #1* (destroyed)	Group #2 (not affected)	Group #3* (uncertain)
2	2	1	7
3	4	2	11
4	0	1	7
5	1	0	1
5 or 5A	2	0	3
6	0	0	1
7	0	0	7
8	0	0	6
St. Croix	0	0	5
Minnesota	0	2	25
	9	6	73

*For a detailed description of the sites destroyed by the Corps of Engineers projects, see Appendix 1. A description of the Group III sites is included in Appendix 2.

Conclusions. Although this report is rather inadequate to determine the real impact of the Corps of Engineers on archaeological sites (there are still those 73 sites for which we have no information on Corps of Engi-

neers impact), it does point up the great need for future surveys along Minnesota's three greatest rivers to determine what effect the Corps of Engineers will have on prehistoric sites.

The importance of these rivers to life was no less important to the original Americans than it is to us today. And it is vital to the history of the American Indian that an attempt be made, if not to preserve, then at least to record the habitation and burial areas that are so numerous along these waterways.

The Corps of Engineers can expect that the professional archaeologists in Minnesota will do everything possible to cooperate with them to see that these ends are achieved.

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Appendix 1.

Description of Sites Destroyed by Corps of Engineers Activity.

1. 21 WA 1 Schilling Site located SE 1/4 Sec 32 T 27N R 21W

   A mound and village site located on Grey Cloud Island, Washington County, Pool #2. Site has been destroyed by raised water level.

2. 21 DK 1 Sorg Site located NE 1/4 NE 1/4 Sec 23 T 115N R 18W

   A habitation site located on Spring Lake, Dakota County, Pool #2. The site is under water now.

3. 21 GD 75 SW 1/4 SE 1/4 Sec 32 T 114N R 15W

   A group of 45 mounds located on Prairie Island, Goodhue County, Pool #3. Thirty-eight mounds are under water, 7 are still above water but are being eroded away by the river.

4. 21 GD 1 Nauer Site located NW 1/4 Sec 9 T 113N R 15W

   A mound and village group located on the southern tip of Prairie Island, Goodhue County, Pool #3. The mounds were destroyed with the construction of Lock and Dam #3.

5. 21 GD 57 Nauer Site located NW 1/4 Sec 9 T 113N R 15W

   Part of Site 1, above, Pool #3. Part of the village and several mounds were destroyed with the construction of the recreational area known as "Commissary Point", a picnic ground.

6. Unnumbered LeSueur and Perrot French Trading Post

   This site is listed as destroyed through "negative evidence". The site is recorded as being on Prairie Island, Goodhue County,

Appendix 1 (Continued)

Pool #3, and all attempts to locate the site have failed. It is thus assumed that because the post was on the water's edge that it is now under water.

7. Unnumbered, Unnamed Sec 34 T 109N R 9W

This was a mound and habitation site at the mouth of the Whitewater River, Wabasha County, Pool #5. The landowner pointed the site out to the State Archaeologist after it had been covered with water.

8. Unnumbered Location T 108N 7W

The site is a group of mounds on Prairie Island, Winona County. The site was covered by a Corps of Engineers levee. Pool 5 or 5A.

9. Unnumbered same location as above

This site, although spared in the first levee construction was buried with the addition of a later levee.

Appendix 2.

Location of Sites Potentially Vulnerable to Damage by Future Construction, Operations and Maintenance Activities. *

POOL 4. 23. WB2 T109 R9

POOL 5. 24. WN18 T107 R8; 25. WN12 T107 R8; 26. WN11 T107 R7

POOL 6. 27. WN6 T106 R5

* In order to find exact locations of these sites contact State Archaeologist Jan E. Streiff, telephone 612-373-5560.

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Early Archaeology

Increase A. Lapham recorded the results of Wisconsin archaeological research which he began in 1836 in The Antiquities of Wisconsin, published in 1850. Although his work was extensive and continued until his death in 1875, if focused on areas other than the Mississippi River Valley. He described sites along the Mississippi River as far north as the La Crosse River; then concluded: "Only an occasional mound was observed along the valley of the La Crosse River; and it is believed that no works of any considerable extent exist above this point on the Mississippi." See Figure 1.

A review of the publications of Lapham, Robert Ritzenthaler, and Charles E. Brown reveal that Wisconsin archaeological and historic sites, especially burial mounds, were extensive. The number of mounds in Wisconsin were estimated to number 15,000. Sites occurred on and near the shores on nearly every stream and lake. In addition to burial mounds, "sites of native villages, camps and workshops; plots of corn hills and garden beds; enclosures; burial places and cemeteries; refuse heaps and pits; cave shelters; shrines; pictograph rocks; boulder mortars, sources of flint, quartz, quartzite and pipestone; lead diggings; copper mining pits; stone heaps and circles; cairns; and trails" are of interest to the Wisconsin archaeologist. Burial mounds, village sites, forts, and pictographs are found in the Mississippi River Valley. See Figure 2.

Recent Archaeology

An important discovery was made in 1945 by two Mississippi River fisher-

men who "saw some aritfacts projecting from the bank which had been undercut by the action of the River." The "Osceola Site" in Grant County is located two miles south of Potosi on the Mississippi River bank. (NW 1/4 of Sec. 14 T.2, N. Range 3, W. of 4th Principal Meridian). Excavation of the burial mound revealed copper implements, as well as projectile points and banner stones. The copper implements provide evidence of the presence of Indians belonging to the "Old Copper Culture" who probably arrived in the State about 3000 B. C.

The site had been damaged, however, by rising river water. Ritzenthaler who described the site in 1946 stated:

> Up to 8 years ago this was the bank of the Grant River, but the installation of a dam at Dubuque raised the water and widened the Mississippi at this point. . . . Test pits revealed that the burial pit extended about 70 feet along the bank, and was about 20 feet wide at this time, but it must have been considerably wider originally judging from the amount of material washed into the river.

No mention was made about intended future disposition of the site. Ritzenthaler also mentioned that another site, Raisbeck, in Grant County had been excavated, but he did not give an exact location. Other mounds were located on the Mississippi River bluffs above Potosi and were mentioned in the 1927 edition of Scenic and Historic Wisconsin.

Dr. Freeman stated that an extensive survey of sites was conducted in Crawford County when the St. Feriole Island buildings were recommended for inclusion in the National Register of Historic Places. St. Feriole Island was originally a prairie between the Mississippi River and the bluffs of Prairie du Chien. It contained many burial mounds which were not effigy shaped.

An article in 1853 by Lapham stated that the mounds "are so near the river that their bases are often washed by floods." During the highest known flood--1826--only the mounds could be seen above the surface of the water. The first fort was built on an Indian mound, as were several French homes. Lapham stated that the mound was excavated but that no remains were found in it. He did note some remains of an "American fort taken by the British in the War of 1812." Lapham, in visiting the mounds in 1852, found them "almost entirely obliterated due to cultivation and the light sandy nature of the materials."

In Pepin County, Ritzenthaler reported the existence of an Indian village site, 2 miles east of Pepin, along a wide terrace to the Mississippi. Pepin is also mentioned as the site of French forts including St. Antoine, built in 1686, above the mouth of Bogus Creek. In Trempealeau County, Nicolls Mound, the Schwert Mounds, and the Trowbridge site have been excavated. Perrot State Park in Trempealeau contains Indian mounds and the site of a log fort erected by N. Perrot, a French explorer, in 1685-6. Indian mounds are also preserved in La Crosse.

In an article published in 1950, "Wisconsin Petroglyphs and Pictographs" Ritzenthaler enumerated the existence of the following petrographs. He did not specify their exact location. Their condition had been unchecked since 1929. Exact location and current condition should be checked with the state archaeologist. In Vernon, La Crosse, Crawford, and Trempealeau Counties, sandstone and limestone cliffs and caves with petrographs were recorded. Larson Cave in Vernon County contained petroglyphs described as being in excellent

condition in 1929, Samual's Cave, La Crosse County, containing petroglyphs and pictographs was first investigated in 1879--and was still in excellent condition in 1929. Galesbluff, La Crosse County, contained petroglyphs carved on soft limestone. Nearly all of the petroglyphs in Trempealeau County in the Trempealeau and Galesville rock shelters have been destroyed--either by road builders, erosion, or tourists. Pictographs were described by L. H. Bunnell in 1897, "a short distance above Prairie du Chien." Ritzenthaler did not report their present condition.

Future Studies

Dr. Freeman mentioned specific sites which have been flooded are located on Lake Pepin, at Trempealeau, and at Wyalusing. In the limited time available, this author could not locate any current publication describing the extent or present condition of sites known to have existed in Wisconsin. The Wisconsin Archaeologist, if reviewed issue by issue, would reveal considerably more data on the above mentioned sites, as well as other, perhaps more important, sites. However, lack of time precluded that examination. An examination of that publication, a review of the files in the historical society, and on-site visits would be required before one could be assured of an accurate analysis of the present condition of the sites.

National Register of Historic Places

In 1966, the National Historic Preservation Act was passed. It provides for comprehensive indexing of the properties in the nation which are significant in American history, architecture, archaeology, and modern culture. The Register is an official statement of properties which merit preservation.

The only Wisconsin archaeological or historic site bordering the Mississippi or St. Croix rivers listed in the Register is in Crawford County on St. Feriole Island in the Mississippi River, at Prairie du Chien.

Astor Fur Warehouse, Brisbois House, Dousman Hotel, Second Fort Crawford, Villa Louis

All of the above structures are remains of the early establishment of Prairie du Chien as an early fur trade, steamship, and railroad center. They were constructed between 1808 and 1864 and most are still under private ownership.

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